CHAPTER 3

FIELD MEASUREMENTS

This chapter describes the methods necessary to record and collect field data. The field parameters *water temperature, pH, dissolved oxygen, and specific conductance* are measured using multiprobe instruments. Additional details on calibration, maintenance, and performance of instruments used to measure these parameters are outlined in Chapter 8 of this manual. The measurement of flow, an important parameter in interpreting data, is also detailed in this chapter.

Recording Field Data

For each sampling trip, record field measurements and observations in a field data logbook or on a field data sheet. This manual does not prescribe any particular system for recording field data. Any mention of a "field data logbook" or "field data sheet" in this document does not refer to a specific document or form. The format for recording field data is left up to the staff responsible for monitoring or as specified in a program or project QAPP.

Field data (bound or loose-leaf sheets) must be maintained on file for a minimum of five years or as defined in a project or program QAPP. It is important to maintain these records since the logbook or data sheets may be the only written record of field measurements. Field-data records are reviewed during the annual technical systems audit or monitoring systems audit.

A good safety precaution against lost field data is to photocopy or electronically scan current data upon returning from the field, keeping these pages on file at the office. The entries discussed below are recorded at each sampling site.

For each visit to an **individual station** where field measurements and samples are collected, record the following:

- station ID
- sampling date
- location
- sampling depth
- sampling time
- sample-collector name(s)
- all measured field parameters and their respective values
- observations

Field physicochemical parameters include part or all of the following:

- dissolved oxygen
- temperature
- specific conductance
- pH

- salinity (tidal waters only)
- Secchi-disk transparency
- days since last precipitation (significant enough to influence water quality)
- flow severity (freshwater streams and rivers)
- stream discharge (freshwater streams and rivers)
- method of stream-discharge measurement (freshwater streams and rivers)

Recording Field Observations

Upon arrival at a sampling site, record observations on the general appearance and condition of the water (for example, color, odor, presence of algae, foam) and other information related to water quality and water use (for example, for fishing or swimming).

Left-bank and right-bank orientation. To be consistent and to help orient others to the location of observations, the convention *left bank–right bank* is used. “Left” and “right” refer to the banks to those sides of an observer when facing downstream.

General Observations

Record field observations to aid in the interpretation of water quality information. Here are some common examples.

Water appearance. General observations on water might include color or an unusual amount of suspended matter, debris, or foam.

Weather. Recent meteorological events that may have affected water quality include heavy rains, a cold front, or very dry or very wet conditions.

Biological activity. Record excessive macrophyte, phytoplankton, or periphyton growth. The observation of water color and excessive algal growth is very important in explaining high chlorophyll *a* or low DO values. Note unusual activities or presence of other aquatic life.

Unusual odors. Examples include hydrogen sulfide, mustiness, sewage, petroleum, chemicals, or chlorine.

Watershed or instream activities. Record instream or drainage-basin activities or events that may affect water quality—for example, bridge construction, shoreline mowing, or livestock watering upstream.

Observations related to water quality and stream uses. If the water quality conditions are exceptionally poor, note that standards are not met in the observations—for example, dissolved oxygen is below minimum criteria. Uses may include swimming, wading, boating, fishing, irrigation pumps, or navigation. This type of information may be used in evaluating compliance with standards.

Specific sample information. Specific information about the sample, such as number of sediment grabs, or type and number of fish in a tissue sample, is required for these sample types. If the sample was collected as part of a complaint or a fish-kill investigation, make a note of this in the *observation* section and use appropriate program codes defined in the *SWQM DMRG*.

Missing parameters. If a scheduled parameter or group of parameters is not collected, note this in the comments.

Other Information Recorded

Water and Sediment Samples

Examples of the general types of chemical samples collected include routine water chemistry, metals in water, metals in sediment, organics and pesticides in water, and organics and pesticides in sediment. Record the method of preservation for each chemical sample. Record the unique tag number for each sample type (water, sediment, or tissue) you submit to the laboratory. The sample tag number is important when contacting the laboratory about a sample. See Chapters 5 and 6 for details on water and sediment collection.

Tissue Samples

Record a description of the general sample habitat where tissue samples were collected. This gives monitoring personnel a reference when sampling similar habitats in following years and at different stations. Also record the species, number of fish per sample, and tag number for each sample submitted to the laboratory. See Chapter 7 for details on tissue collection.

Biological Samples

Procedures for conducting biological and habitat monitoring are outlined in *Surface Water Quality Monitoring Procedures, Volume 2* (TCEQ publication RG-416). See also Appendix A.

Field Measurements

Water samples (including bacteriological) are generally collected before field measurements are taken. If meeting hold times for associated water and bacteriological samples is an issue, field measurements (including flow) may be taken first. Keep in mind that the water samples must be collected from an undisturbed area, and multiprobe instruments must be allowed to stabilize. See Chapters 4 and 5 for details on collecting bacteriological and water quality samples. See Chapter 8 for details on calibration and maintenance of multiprobe instruments. Chapter 9 provides a list of required equipment.

Where to Collect Field Measurements

For freshwater-stream samples, the centroid of flow should be accessible for sampling physicochemical parameters—by bridge, boat, or wading. Field measurements should be taken as close to the centroid of flow as possible when the stream appears to be completely mixed from shore to shore. **The *centroid* is defined as the midpoint of a portion of the stream width which contains 50 percent of the total flow**. In streams, measurements are generally taken upstream of a bridge. This is to avoid any influence runoff from the bridge might have on getting a representative measurement.

Field measurements in reservoirs, estuaries, and bays are generally collected by boat. In tidally influenced portions of streams and rivers, samples are generally collected from the channel midpoint by bridge or boat. Most tidal streams are too deep for wading to the channel midpoint. Sampling from the shoreline of any water body is the least acceptable method. If shoreline sampling is the only option, the TCEQ recommends moving to a more accessible location.

Depth of Field Measurements

Streams and Shallow Rivers

Less than 0.50 m. If the water depth of a stream or shallow river is less than 0.50 m, take field measurements at a depth equal to one-third of the water depth measured from the surface. Report the actual measured depth.

Greater than 0.50 m but less than 1.5 m. If the water depth at the sampling point of a shallow stream or river is greater than 0.50 m, but less than 1.5 m, for dissolved oxygen, temperature, pH, and specific conductance measure at a depth of 0.30 m below the surface.

1.5 m or greater. If the sampling point of a shallow stream or river is 1.5 m deep or deeper, make a vertical profile for dissolved oxygen, temperature, pH, and specific conductance using a multiprobe instrument. If a vertical profile is not practical, report those measurements from a depth of 0.30 m. The measurement depth is more accurately determined from the depth sensor on a multiprobe instrument rather than depth labels on the cable. See Chapter 8 for details on "Calibrating the Depth Sensor."

Vertical Profiles in Rivers, Reservoirs, Bays, and Estuaries

Procedures for measuring depth or vertical profiles in reservoirs, deep rivers, bays, and barge and ship channels greater than 1.5 m in depth are outlined below. See the *SWQM DMRG* for detailed information on data reporting. Take measurements at specific depths to determine if a water body is stratified—if so, certain criteria apply to the mixed surface layer. In the absence of profile data, a single surface sample (0.30 m) is adequate.

For information on the *mixed surface layer,* refer to the most recent revision of the TCEQ's *Guidance for Assessing and Reporting Surface Water Quality in Texas*. See Appendix A.

Reservoirs, inland streams, bays, and barge channels with depths 1.5 to < 3.0 meters. In reservoirs, inland streams, bays, and barge channels (for example, the Intracoastal Waterway) which are 1.5 to < 3.0 m deep, record measurements at 0.30 m below the surface, at mid-depth, and at 0.3 m above the bottom.

Reservoirs, inland streams, and bays with depths ≥ 3.0 meters. In reservoirs, inland streams, and bays which are 3.0 meters or greater in depth, record measurements at 0.30 m below the surface and then at 1.0 m and each subsequent 1.0 m interval. For the final measurement, take a reading 0.30 m above the bottom, if possible. If the remaining distance is less than 0.3 m, a final measurement is not required. The intervals may be extended to 3.0 m in reservoirs, if the total depth exceeds 18 m. All of the intervals, however, must be equal—1, 2, or 3 meters—and consistent with intervals used in earlier and subsequent field events. This helps determine compliance with water quality standards.

Coastal ship channels with depths ≥ 3.0 meters. In coastal ship channels which are 3.0 m or greater in depth, record measurements at depths of 0.30 m below the surface and then at 3.0 m and each subsequent 3.0 m interval. For the final measurement, if the distance from the last reading to the bottom is greater than 1.0 m, take a reading at 0.30 m above the bottom. If the distance is equal to or less than 1.0 m, do not take another reading.

Field Parameters

This section summarizes information, guidelines, and minimum requirements that apply to the following field measurements; DO, specific conductance, pH, 24-hour DO, salinity, chlorine residual, and Secchi-disk transparency.

Required Monitoring Equipment

See Chapter 9 for the list of required SWQM equipment.

Water Temperature

Parameter Code 00010

Record the water temperature data to the nearest tenth of a degree Celsius (°C).

Equipment

- A multiprobe instrument (see Chapter 8).

Procedures for Sampling

Measure temperature directly from a water body at one or more depths specified in "Depth of Field Measurements." Allow the sensors to equilibrate for at least 2 minutes before recording the temperature. The temperature sensor does not require routine calibration but must be checked for accuracy during routine instrument maintenance. See Chapter 8, "Temperature Sensor," for additional information on temperature sensor checks.

pH

Parameter Code 00400

Record pH data to the nearest tenth of a standard unit.

Equipment

- A multiprobe instrument, calibrated according to "pH Sensor," Chapter 8.

Procedures for Sampling

Measure pH directly from a water body at one or more depths specified in "Depth of Field Measurements." The pH sensor is calibrated each day of use for multiprobe instruments. See Chapter 8, "Calibrating and Maintaining Multiprobe Instruments." Allow the sensors to equilibrate for at least two minutes before recording pH.

Dissolved Oxygen

Parameter Code 00300

Record dissolved-oxygen data to the nearest tenth of a mg/L.

Equipment

- A multiprobe instrument, calibrated according to "Dissolved Oxygen Sensor," Chapter 8.

Procedures for Sampling

Measure DO directly from a water body at one or more depths specified in "Depth of Field Measurements." The DO sensor is calibrated each day of use for multiprobe instruments. See Chapter 8, "Calibrating and Maintaining Multiprobe Instruments."

The DO probe must be allowed to stabilize for at least two minutes before DO is recorded. Since dissolved oxygen takes the longest to stabilize, record this parameter **after** temperature, specific conductance, and pH. For profile measurements, allow the DO probe to stabilize for at least two minutes before taking the initial reading. For each subsequent depth allow the DO reading to stabilize before recording the measurement.

24-Hour Dissolved Oxygen

Sampling for Compliance with Standards for the Aquatic-Life Use

Parameter Codes 89857 and 89855

Each classified water body in the TSWQS is assigned an aquatic-life use (ALU)—*exceptional, high, intermediate, limited,* or *minimal*—based on physical, chemical, and biological characteristics. To protect these uses, 24-hour average DO criteria and absolute DO minimum criteria are assigned to each ALU category.

For detailed information on DO criteria for classified and unclassified water bodies and on the use of 24-hour DO data in assessing aquatic-life-use support, see the most recent revision of the TCEQ's *Guidance for Assessing and Reporting Surface Water Quality in Texas* (see Appendix A).

Unattended Data Collection—Dissolved Oxygen

Why Collect 24-Hour Data?

Dissolved oxygen sampling for compliance with ALU standards is targeted to water bodies where low instantaneous DO levels indicate only partial support or nonsupport of designated ALUs. This sampling requires intensive monitoring with automated equipment that is preset to record and store field measurements over one 24-hour period.

When to Take Measurements

Twenty-four-hour DO monitoring events can be conducted year-round. To ensure unbiased, seasonally representative data, samples are allocated to various times of the year. Collect one-half to two-thirds of the samples during the *index period* representing warm-weather seasons of the year, March 15–October 15 (Figure 3.1). Of the total allocated to the index period a subset of the samples are to be collected during the *critical period* of the year (July 1–September 30)—when minimum streamflows, maximum temperatures, and minimum DO concentrations typically occur in Texas streams. Collect a minimum of one-fourth to a maximum of one-third of the samples (allocated to the index period) during the critical period. The remainder of the samples can be collected outside the index period. **Approximately one month must separate each 24-hour sampling event. The minimum number of samples collected in a year is two—one within the index period and one within the critical period**.

Note: For specific guidance on data requirements for determining DO standards compliance refer to the most current version of the *Guidance for Assessing and Reporting Surface Water Quality in Texas* (see Appendix A).

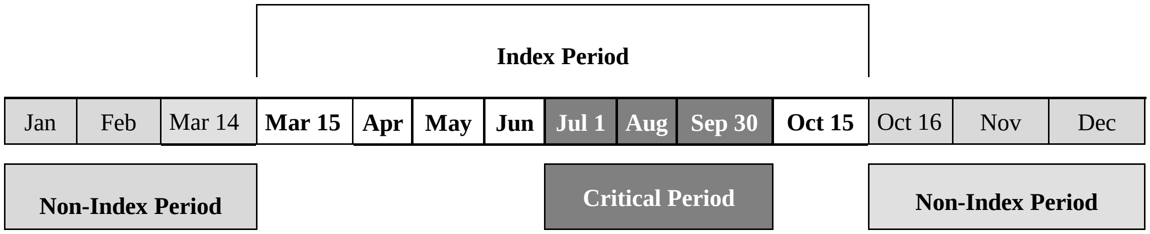


Figure 3.1. Index, non-index, and critical periods.

Stream Discharge Requirements

In flowing freshwater streams and rivers, a *discharge measurement must be taken during the period of deployment, where possible*. If the discharge is less than the 7Q2 in a perennial stream, the DO criterion does not apply, and 24-hour data are not evaluated for compliance with standards. Discharge measurements are not required for tidal streams, reservoirs (including riverine portions), bays, or estuaries. For larger streams, **only** where discharge cannot be measured, a flow-severity value may be submitted.

Equipment

Please refer to Chapter 8 for specific information on instrument setup and calibration.

Frequency of Measurements

The preferred measurement interval is no more than once per 15 minutes, and no less than once per hour. Thus, the minimum total number of measurements over the 24-hour period is 25. Meeting the minimum would require programming an instrument to record data for more than 24 hours. Those leaving instruments out for several days should report the first 24-hour period after initial stabilization. See “Acclimating to Ambient Conditions,” below, for additional information.

Sometimes a complete 24-hour data set is not possible. For example, if there are 20 measurements instead of 24, a time-weighted average needs to be calculated.

A TWA is calculated using the following formula:

$$\text{TWA} = \left(\frac{T_2 - T_1}{24}\right) \times \left(\frac{DO_1 + DO_2}{2}\right) + \left(\frac{T_3 - T_2}{24}\right) \times \left(\frac{DO_2 + DO_3}{2}\right) + \left(\frac{T_4 - T_3}{24}\right) \times \left(\frac{DO_3 + DO_4}{24}\right) + \ldots$$

DO = DO concentration in mg/L
T = Time interval

Acclimating to Ambient Conditions

Allow the instrument time to acclimate to ambient conditions by setting its start time at least an hour after deployment. Unlike the short warm-up time for instantaneous measurements, extended monitoring takes a little longer so that all measurements are collected under the same conditions. In cases where the instrument begins recording data shortly after deployment, the first measurement should not be included in the data set.

Where to Take Measurements

Shallow streams. For purposes of determining compliance with the 24-hour average criteria, samples collected at the surface (0.3 m) will be considered representative of the mixed surface layer.

Refer to “Depth of Field Measurements” for guidelines on deployment depths.

The placement of the instrument is specific to each sample location. Remember, the main goal is to place the instrument in a location that will best represent conditions of that water body. Avoid backwater areas, stagnant pools, shallow areas, or areas near the bank. Where possible, place instruments away from the bank in flowing water.

Due to the varied conditions encountered in Texas, the following are general guidelines. In general, suspend instruments from cables or chains attached to a bridge piling, or over a hanging tree or some other structure that will allow their suspension at the correct depth. To protect the instrument from damage, place it in a guard (usually a piece of PVC pipe slightly larger than the instrument) with slits or holes that allow water to flow through. Avoid laying instruments on soft stream bottoms where sediment can interfere with the probes. Cinder blocks, boulders, or other stable objects can be used to position an instrument off the bottom in cases where there is no overhanging structure or the bottom is soft (see Figure 3.2).

Deep streams, reservoirs, and bays. Deploy instruments in the *mixed surface layer*. Determine the location of that layer by taking profile measurements (refer to “Vertical Profile Depth”).

Deploy a multiprobe instrument between a depth of 0.3 m (from the surface) and half the depth of the mixed surface layer. For example, if the mixed surface layer is 3 m deep, deploy the instrument between 0.3 m and 1.5 m. This is only required when the water body is stratified.

Figure 3.2. Deploying an instrument for 24-hour monitoring.

For additional information on the *mixed surface layer* see the most recent revision of the TCEQ’s *Guidance for Assessing and Reporting Surface Water Quality in Texas* (see Appendix A).

Suspend instruments from buoys, pilings, or structures that allow their placement at the correct depth. In pools, reservoirs, bays, or estuaries, sample the central water mass, rather than side channels, backwater areas, or shallow areas near the bank.

When to Collect Other Routine Samples

Collect other routine field measurements and water samples either deployment or when retrieving a multiprobe instrument that is recording 24-hour data.

Priority for Scheduling 24-Hour Sampling Events

When prioritizing 24-hour sampling events, consider the following:

- water bodies on the 303(d) List
- water bodies with concerns for low DO (too few samples available for full-use assessment)
- occurrence of low or very high DO concentrations during the day
- water bodies with trends that indicate declining DO concentrations
- water bodies contributing to an ecoregion data set

Data Reporting

24-hour data. Data submitted for a 24-hour DO event include:

- minimum value
- maximum value
- 24-hour average
- number of measurements

Reporting other field measurements—water temperature, specific conductance, pH, and salinity —collected as part of the 24-hour deployment is optional. See the *SWQM DMRG* for a list of parameter codes and detailed information on reporting these parameters.

Non–24-hour data. All grab-sample data or instantaneous measurements associated with a 24-hour event must be reported separately. **They are not composites and therefore cannot be considered part of a 24-hour event.** Examples include Secchi-disk transparency; instantaneous DO, temperature, pH, and specific-conductance measurements; stream discharge, routine water chemistry, and bacteria data, or simply everything that was not downloaded from the multiprobe instrument.

QC Checks

It is important to collect accurate 24-hour DO data. These data are used for assessing standards compliance and whether a water body is capable of supporting the designated or presumed ALU. **Calibration and post calibration checks must be done with each 24-hour deployment. The difference between the calibration and post calibration for DO must be within ± 0.5 mg/L or ± 6 percent saturation.** Post-calibration error limits for optional 24-hour parameters are listed in Chapter 8.

The time between calibration and the post-calibration check may vary. Some instruments are left out for 48 hours. In other cases, one instrument may be used for several 24-hour samplings before the post-calibration check. This is not the preferred method but is acceptable as long as the instrument passes the post-calibration check. The risk of expanding the time between calibration and the post-calibration check is the loss of data if the instrument fails the QC checks.

Specific Conductance

Parameter Code 00094

Record specific conductance measurements in microsiemens per centimeter (µS/cm); to three significant figures if the value is greater than 100 µS/cm and to two significant figures if the value is less than 100.

Equipment

- A multiprobe instrument, calibrated according to "Conductivity Sensor," Chapter 8.

Procedures for Sampling

The specific conductance function is calibrated each day of use for multiprobe instruments. See Chapter 8, "Calibrating and Maintaining Multiprobe Instruments." Measure specific conductance, like other field parameters, directly from a water body at depth(s) specified in "Depth of Field Measurements." Allow the conductivity probe to equilibrate for at least two minutes before recording specific conductance.

A common physical problem in using a specific-conductance probe is trapping of air bubbles. Air in the probe is indicated by unstable specific conductance values fluctuating up to ±100 µS/cm, which can be minimized by slowly, carefully placing the probe into the water and, when the probe is completely submerged, quickly moving it through the water to release any air bubbles.

Salinity

Parameter Code 00480

In 1978, oceanographers redefined salinity in the *Practical Salinity Scale* as the conductivity ratio of a seawater sample to a standard KCl solution. PSS is a ratio with no units but is expressed in ppth which is approximately *grams of salt per kilogram of solution* (Stewart, 2008). Salinity is calculated from specific conductance and temperature. Multiprobe instruments compute salinity from specific conductance and temperature based on Standard Method 2520b, 18th edition, 1989. The method detection limit for the equation used by field instruments is 2.0–42.0 parts per thousand (ppth).

Equipment

- Multiprobe instrument, calibrated according to "Conductivity Sensor," Chapter 8.

Procedures for Sampling

In estuarine waters, salinity is a relevant and meaningful parameter. Often, salinity may be low, approaching that of freshwater. Nevertheless, this is useful information. Determine if a station is estuarine from historical records (cases where salinity is ≥ 2.0 ppth) and always report salinity at this station, regardless of the salinity during periods of high flow. Measure salinity, like other field parameters, directly in situ at the depths specified in "Field Measurements." Record salinity data in parts per thousand, to the nearest 0.1 ppth, for tidal streams, estuaries, or bays. Report values less than 2.0 ppth as "< 2.0 ppth" rather than the actual value.

Do not report salinity from freshwater or inland (brine) locations. These values are not comparable to salinity measurements in marine or tidally influenced locations. They include other salts depending on the underlying geography. In the absence of salinity data, the staff can calculate salinity by using temperature and specific conductance.

Field Measurements from a Bucket

If it is not possible or unsafe to measure *in situ*, use a container (for example, a Nalgene or plastic bucket) to measure DO, water temperature, pH, and specific conductance. Take care to ensure a measurement representative of in-stream conditions.

When taking field measurements with a multiprobe instrument, remember to place the sonde directly in the water body to be sampled and then allow it to equilibrate while water samples are collected. Only use a multiprobe instrument and bucket to measure field parameters in atypical circumstances.

- Do not use a bucket if the multiprobe instrument can be put directly into a water body. Use a bucket in atypical situations when such insertion is not practical (extreme high flows, a bridge too high for the cable, lack of safety).
- Choose a bucket that is large enough to allow full immersion of the probe.
- Before filling, bring the temperature of the bucket to the same temperature as the water.
- Place the probe in the bucket immediately, before the temperature changes.
- Protect the bucket from direct sunlight and strong breezes before and during field measurements.
- Allow the probe to equilibrate for at least two minutes before recording field parameters (DO, water temperature, specific conductance, and pH).
- For details on collecting water samples from a bucket, see Chapter 5.

Secchi-Disk Transparency

Parameter Code 00078

Importance of Secchi-Disk Transparency Data

Secchi-disk transparency remains an important secondary parameter for assessing *eutrophication*—the natural aging process in reservoirs and lakes—and for determining trends in water clarity. Eutrophication is accelerated by human activities that add nutrients to lakes, reservoirs, and the surrounding watersheds. Section 314 of the federal Clean Water Act of 1987 requires all states to classify lakes and reservoirs according to the trophic state. The TCEQ evaluates and ranks major Texas reservoirs and lakes using Carlson's trophic-state index (TSI). The TSI was developed to compare among reservoirs, Secchi-disk depths, chlorophyll *a* and total phosphorus concentrations obtained during routine reservoir monitoring (Carlson 1977). Although chlorophyll *a* is the most direct measure of algal biomass, Carlson's TSI uses Secchi-disk depth as the primary factor. Carlson's TSI is a useful tool for assessing the current condition of a reservoir or lake and monitoring it for change over time. It is important to pair nutrient sampling with Secchi-disk transparency whenever possible. For additional information see the "Nutrient Sample Collection" section in Chapter 5. Secchi-disk measurements in streams are also important for interpreting nutrient data. For bays and estuaries the Secchi disk is the preferred method. For shallow streams and rivers the Secchi tube is the preferred method.

Equipment

- Secchi disk, 20 cm in diameter attached to a calibrated line (calibrated in metric increments) or fixed pole

- Secchi tube (optional)
- measuring tape (metric)

Procedures for Sampling

Measure Secchi-disk transparency directly in the water body wherever conditions allow. The Secchi disk should be clean, weighted and suspended on a metric-calibrated chain, wire, or Dacron line (not nylon or cotton because stretching may cause erroneous readings). A standard Secchi disk is 20cm in diameter and divided into four sections alternating black and white (see Figure 3.3). Another option is to attach the Secchi disk to a PVC pole calibrated in metric units. A Secchi disk mounted on a pole is beneficial for stations affected by wind and waves that make reading a traditional Secchi disk difficult. Record the Secchi-disk transparency in meters. Remove sunglasses before making a measurement.

Normal Turbidity

Following are procedures for measuring Secchi-disk transparency under normal conditions:

- Lower the Secchi disk vertically in a location shielded from direct sunlight. Glare from the water's surface will affect the accuracy of the measurement. Don't wear sunglasses.
- Slowly lower the disk until it disappears from view. The viewer should maintain an eye level of less than 2 meters above the water's surface. Note the depth from the surface at which the disk disappears from view.
- Slowly raise the disk until it becomes visible. Note the depth at which the disk reappears.
- Compute the average (mean) of the two depths noted and record the value in the field logbook. The recorded average value is the Secchi-disk transparency.

High Turbidity

(Muddy Water)

To measure Secchi-disk transparency in highly turbid water:

- If necessary, use a bucket to measure Secchi-disk transparency in streams with very high turbidity and high velocity. Fill the bucket from the centroid of flow, being careful not to disturb the substrate.

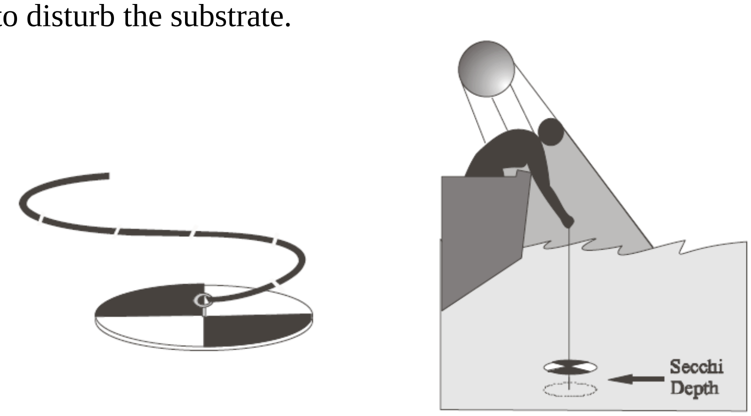


Figure 3.3. Secchi disk (Ministry of the Environment, Ontario, Canada, 2003).

- Follow the steps above for measuring the Secchi-disk depth within 30 seconds after raising the filled bucket from the water surface. If the solids settle resuspend by stirring and then quickly take the measurement.
- Record Secchi-disk transparency measurements in meters to two significant figures.

Low Turbidity

(Clear Water)

To measure Secchi-disk transparency under very clear water with low turbidity:

- Some bodies of water will be so clear and shallow that it will not be possible to lower the Secchi disk until it disappears from view.
- Measure and record the depth at the deepest point accessible.
- Report Secchi-disk transparency as greater than the deepest depth measured.

Example of low turbidity: South Fork Rocky Creek is a small (< 1 ft^3/s flow) clear stream. The stream in the vicinity of the sampling site is less than 1 meter deep and the bottom is clearly visible everywhere. However, a pool is located in the stream next to a bridge. The maximum depth of the pool is 2.6 meters, at which depth the Secchi disk is still visible. Therefore, Secchi-disk transparency for South Fork Rocky Creek is recorded as > 2.6 m.

Secchi Tube

Stream transparency can be measured with either a Secchi disk or Secchi tube. The tube varies in length and is made of narrow clear plastic, with a release valve at the bottom (see Figure 3.4). The bottom end of the tube has a small Secchi-disk symbol. The standard dimensions of a Secchi tube for SWQM in Texas are 120 cm long × 4 cm in diameter.

1. Fill the tube with sample water just until the image at the bottom of the tube is no longer visible when looking directly through the water column at the image—having taken care to take readings in open but shaded conditions. Avoid direct sunlight by turning your back to the sun. Remove sunglasses before making a measurement.
2. Look down into the tube and release water through the valve until the symbol is just visible.
3. Read the turbidity on the column at the bottom of the meniscus (bottom of the curve in the water surface).
4. Record the depth of the water in meters. If the symbol is visible when the tube is full, the transparency reading is greater than 0.60 meters (see Figure 3.4).

Figure 3.4. Secchi tube.

Note: If you have the type of Secchi tube that includes a string for lowering and raising the disk, average the measurements taken where the disk disappears and then reappears.

Chlorine Residual

Chlorine has an effect on bacteria, BOD, cyanide, semivolatile organics, pesticide, and herbicide samples. Chlorine residual should be analyzed from samples collected downstream of chlorinated effluent discharges or in areas where the presence of chlorine is suspected when these types of samples are collected. If chlorine is present and these samples are to be analyzed for bacteria, BOD, semivolatile organics, pesticides, and herbicides, the samples must be treated with sodium thiosulfate ($Na_2S_2O_3$) to remove the chlorine. Cyanide samples are treated with ascorbic acid to remove chlorine. See Chapters 4 and 5 for details on the treatment of samples in the presence of chlorine. Test strips or a standard chlorine residual test may be used as a way to determine the presence or absence of residual chlorine in the field.

Field Data Reporting

Values must be in final form before reporting to the TCEQ central office (see Table 3.11). See the *SWQM DMRG* for detailed information on data reporting.

General Rounding Rules

Every measurement has a degree of uncertainty, so field measurements are rounded before being submitted to the TCEQ SWQMIS database. Round numbers by dropping digits that are not significant, according to *Standard Methods* (APHA, et al. 2005). In decimals, if the digit *6, 7, 8,* or *9* is dropped, increase the preceding digit by one unit. For example, *6.68* rounds to *6.7*. If *0, 1, 2 3,* or *4* is dropped, do not change the preceding digit. For example, *6.62* rounds to *6.6.* If *5* is dropped, round off the preceding digit to the nearest even number. For example, *2.25* rounds down to *2.2*; *2.35* rounds up to *2.4*. See Table 3.1.

Other Field Observations

Days Since Last Significant Precipitation

Parameter Code 72053

"Significant" precipitation is defined as any amount that visibly influences water quality. Water quality in small to medium streams and in the headwaters of many reservoirs is influenced by runoff during and immediately after rainfall. This influence is site specific and poorly studied. To understand and regulate the adverse effects of runoff, the SWQM Program would like to associate recent rains or melted snow with ambient water quality, using *days since last significant precipitation*, which can also be used to indicate periods of insufficient rainfall and long-term drought.

Using your best professional judgment, record the number of days—rounded to the nearest whole number—since a rainfall that may have influenced water quality. Here are some guidelines:

- If it is raining when the sample is collected, or has rained within the last 24 hours, report a value of *< 1*.

- If it has been a long time since a significant rain, record either the actual number of days, if known, or a ‘greater than’ value—for example, > *60 days*.
- If your confidence about the recent history of precipitation is low, don’t report a value. See the *SWQM DMRG* for detailed information on data reporting.

Flow Severity

Parameter Code 01351

Record a flow-severity value for each SWQM visit to freshwater streams or rivers (**nontidally influenced**) and report the value to the TCEQ central office. Do not report flow severity for reservoirs, lakes, bays or tidal streams. It should be recorded even if it was not possible to measure flow on a specific sampling visit. See the *SWQM DMRG* for detailed information on data reporting.

No numerical guidelines are associated with flow severity, an observational measurement that is highly dependent on the water body and the knowledge of monitoring personnel. It is a simple but useful piece of information when assessing water quality data. For example, a bacteria value of 10,000 with a flow severity of *1* would represent something entirely different than the same value with a flow severity of *5*. See Table 3.2 for detailed descriptions of flow-severity values.

Real-time flow data for U.S. Geological Survey sites statewide and International Boundary and Water Commission sites in the Rio Grande Basin are available on the Web (see Appendix A). This is useful information in determining actual flow, flow conditions before sampling, and flow severity. Flow severity in streams with managed flows—especially seasonal, for irrigation—can be difficult to determine. Flow severity in these streams should not be based on seasonal norms. For example, flow due to irrigation demands creates a “normal” flow of 500 cfs during the summer months and a “normal” flow of 50 cfs during the winter months where irrigation flows stop. This information would be difficult to interpret.

Table 3.1. Final format for reporting field data (rounding, significant figures).

Parameter	Parameter Code	Final Form for Field Data (Rounding, Significant Figures)
Water temperature (°C)	00010	Report temperature to the nearest tenth in degrees Celcius. (example: *25.94* to *25.9*, or *26.97* to *27.0*)
pH (s.u.)	00400	Report pH to the nearest tenth in pH standard units. (example: *7.94* to *7.9*, or *7.97* to *8.0*)
DO (mg/L)	00300	Report dissolved oxygen to the nearest tenth in mg/L. (example: *5.94* to *5.9*, or *6.97* to *7.0*)
Specific conductance (µS/cm)	00094	Report specific conductance to only three significant figures if the value exceeds 100—for example: *1532* to *1530*. Do not report ORP, which is displayed by some multiprobe instruments. For values < 100µS/cm follow standard rounding rules and report the nearest whole number. For example, report *88.7* as *88 µS/cm*.
Salinity (ppth)	00480	Report salinity values above 2.0 ppth to the nearest tenth in parts per thousand. Do not report salinity from freshwater or inland (brine) locations. In estuarine waters report the actual values displayed by the instrument above 2.0 ppt, and values less than 2.0 as *< 2.0* (examples: *0.85* to *< 2.0*; *1.5* to *< 2.0*). Determine if a station is estuarine (experiencing periods where salinity is > 2.0 ppth), and always report salinity at this station, regardless of salinity during periods of high flow. In the absence of salinity data, use specific conductance and temperature to calculate salinity.
Secchi disk (meters)	00078	Report Secchi-depth transparency in meters to two significant figures (examples: *0.35 m* or *1.3 m*).
Days since last significant precipitation (days)	72053	Report whole numbers. If it is raining when the sample is collected, or has rained within the last 24 hours, report a value of *< 1*. Otherwise report the actual number, if known, or a 'greater than' value.
E. coli (MPN/100 mL)	31699	First step: round the result to the nearest whole number to remove decimals. Second step: round to two significant figures (example: *347.1* to *347* to *350*). Adjust < and > results based on dilution. Do not report "zero" but *< 1*.
Enterococci (MPN/100 mL)	31701	*First step:* round the result to the nearest whole number to remove decimals. *Second step:* round to two significant figures (example: *347.1* to *347* to *350*; *9.7* to *10*). Adjust < and > results based on dilution. Do not report "zero" but *< 1*.
Fecal coliform (colonies/100 mL)	31616	Always report fecal coliform densities as a whole number. If no colonies are detected, report a less than value based on the volume filtered. For example: report *< 1* (100 mL filtered), *< 4* (25 mL filtered), or *< 10* (10 mL filtered). For concentrations > 100, report two significant figures. Do not record "TNTC" or "0/100 mL."
Flow (**Stream Discharge)** (ft^3/s)	00061	Report instantaneous flow **values less than 10 but greater than 0.1 ft^3/s** to the nearest tenth (example: *9.35* to *9.4*). Report flow **values greater than 10 ft^3/s** to the nearest whole number (example: *20.62* to *21*). Actual flow **values less than 0.1 ft^3/s but greater than or equal to 0.01 ft^3/s** are reported and not subject to rounding (example: report *0.07* as *0.07*). Report flow **values < 0.01 ft^3/s** as *< 0.01*. When there is **no flow** (pools), report 00061 as *0.0*. When there is no water, do not report a value for 00061.
Flow severity (1—No Flow, 2—Low, 3—Normal, 4—Flood, 5—High, 6—Dry)	01351	Report flow severity for freshwater streams and rivers only. When there is no flow (pools), report a flow severity of *1*, and the instantaneous flow (00061) as *0.0 ft^3/s*. If the stream is dry, record only the flow-severity value of *6*.
Note: For details on reporting final data sets to the TCEQ, see the *SWQM DMRG*.		

Table 3.2. Flow-severity values.

Severity Value		Description
1		**No Flow.** When a flow severity of ***1*** is recorded for a sampling visit, record a flow value of 0 ft^3/s (using parameter code 00061) for that sampling visit. A flow severity of *1* describes situations where the stream has water visible in isolated pools. There should be no obvious shallow subsurface flow in sand or gravel beds between isolated pools. "No flow" not only applies to streams with pools, but also to long reaches of streams that have water from bank to bank but no detectable flow.
2		**Low Flow.** When streamflow is considered low, record a flow-severity value of ***2*** for the visit, along with the corresponding flow measurement (parameter code 00061). In streams too shallow for a flow measurement where water movement is detected, record a value of < 0.10 ft^3/s. In general, at low flow the stream would be characterized by flows that don't fill the normal stream channel. Water would not reach the base of both banks. Portions of the stream channel might be dry. Flow might be confined to one side of the stream channel. ***Note:*** Use a stick or other light object to verify the direction of water movement. Make sure the movement is downstream and not the effect of wind.
3		**Normal Flow.** When streamflow is considered normal, record a flow severity value of ***3*** for the visit, along with the corresponding flow measurement (parameter code 00061). What is normal is highly dependent on the stream. Normality is characterized by flow that stays within the confines of the normal stream channel. Water generally reaches the base of each bank.
4		**Flood Flow.** Flow-severity values for high and flood flows have long been established by the EPA and are not sequential. Flood flow is reported as a flow severity of ***4***. Flood flows are those that leave the confines of the normal stream channel and move out onto the floodplain (either side of the stream).
5		**High Flow.** High flows are reported as a flow severity of ***5***. High flow would be characterized by flows that leave the normal stream channel but stay within the stream banks.
6		**Dry.** When the stream is dry, record a flow-severity value of ***6*** for the sampling visit. In this case the flow (parameter code 00061) is not reported, indicating that the stream is completely dry with no visible pools.

Pool Characteristics (Flow Severity = 1)

Parameter Codes 89864, 89865, 89869, and 89870

Data collection as part of routine water quality monitoring is conducted under all flow conditions including intermittent streams with pools (flow severity = 1). When sampling in a pool it is important to record basic information about its size, to better define attainable and beneficial uses for aquatic life and contact recreation. Pool characteristics (other than size) are also needed to determine the aquatic-life use supported by pools of different sizes and persistence. A pool is defined as anything greater than or equal to 10 meters in length and greater than or equal to 0.4 m in depth.

To aid in defining pools, record and report the following information for the main pool sampled:

- maximum pool width (meters)
- maximum pool depth (meters)
- pool length (meters)

To determine the percent pool coverage, check a reach that extends a total of 500–800 meters upstream and downstream of the monitoring site. Report the percent pool coverage in a 500 m–800 m reach.

Reporting the Flow-Measurement Method

Parameter Code 89835

The method (or instrument) used to measure flow is noted by reporting a method category number.

1—flow-gauge station (USGS, IBWC)

2—electronic (example, Marsh-McBirney)

3—mechanical (example, pygmy meter)

4—weir or flume

5—Doppler (example, FlowTracker)

Flow

Parameter Code 00061

Flow is required at all routine freshwater stream monitoring sites. Always measure flow, read a USGS (or IBWC on the Rio Grande) flow gauge, or obtain a flow value at a later date from the USGS or IBWC. Flow from gauging stations may only be reported with data collected immediately adjacent to that site, unless a case can be made that no major tributary or wastewater discharge is located between the gauge station and monitoring site.

Report flow values in cubic feet per second (ft^3/s). Flow values must be in final form before they are reported to the TCEQ central office (see Table 3.1). See the *SWQM DMRG* for detailed information on data reporting.

Considerations when Measuring Flow

When measuring flow there are two things to keep in mind. Consider measuring flow first in order to delay collection of chemical and biological water samples with limited holding times. If flow is measured first, take care not to deploy a multiprobe instrument or to collect water samples in the area disturbed during flow measurement.

Exceptions to Flow-Reporting Requirements

There are two exceptions to the flow-reporting requirements:

No flow and pools. If there is no flow at a stream site, and accessible, isolated pools remain in the stream bed, collect and report the required field data and laboratory samples from the pools and report instantaneous flow. Under these conditions, report flow (ft^3/s) as zero (parameter code 00061 = 0.0). The reported flow severity value should be 1 (parameter code 01351 = 1). Pools may represent natural low-flow conditions in Texas streams, and the chemistry of these pools will reveal natural background conditions.

Dry. If the stream bed holds no water, no sampling is required. Report that the stream was “dry” in the observations and record a value of *6* (meaning ‘dry’) for flow severity (parameter code 01351 = 6). No value is reported for flow (parameter code 00061) since there is no water. A data record must be sent to the TCEQ central office if the site is on the routine monitoring schedule.

Methods for Measuring Flow

Instantaneous Flow Measurement

Instantaneous flow must be measured at water quality monitoring visits to sites where there are no nearby flow gauges. The method described in this manual is based on the U.S. Geological Survey’s method for streamflow measurement (Rantz 1982).

Equipment

Flow Meter

One of the following or an equivalent:

- Marsh-McBirney electronic meter
- Son-Tek FlowTracker (Doppler, handheld)

Additional Equipment

- top-setting wading rod (measured in tenths of feet)
- tape measure (with gradations every tenth of a foot)

Procedure for Measuring Flow

1. Site Selection

The key to successful flow measurement is site selection. Select a stream reach with the following characteristics (see Figure 3.5):

- Find a straight reach with laminar flow (parallel threads of velocity) that extends from bank to bank. The depth and velocity should be relatively uniform. This is typically found in unobstructed riffles, runs or glides.

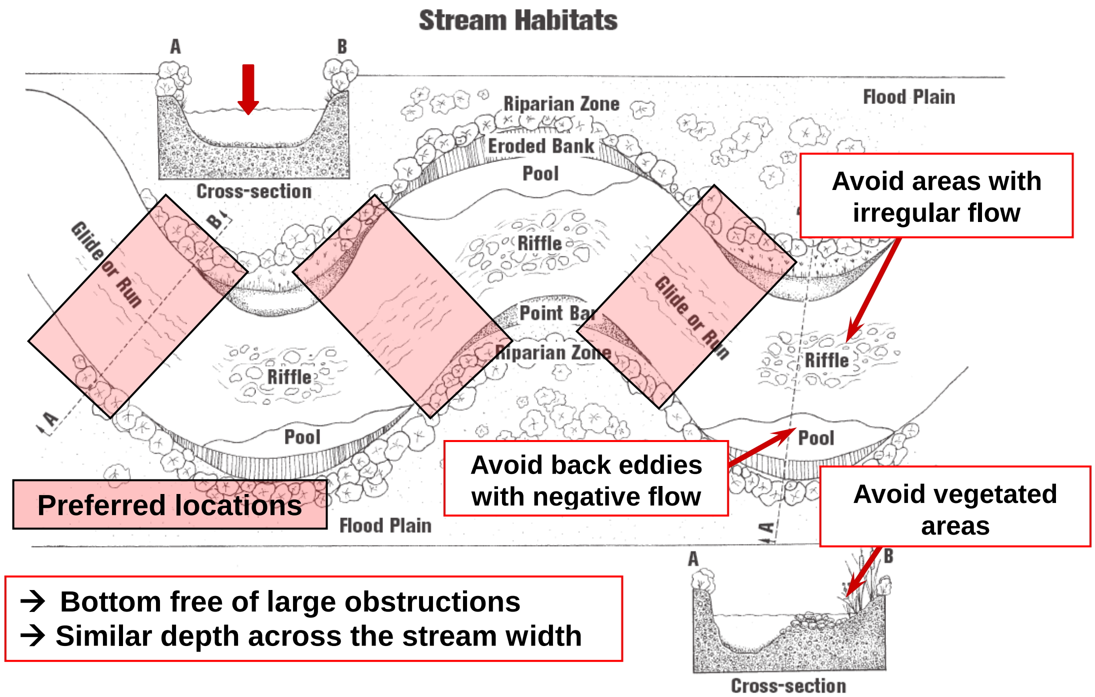


Figure 3.5. Selecting a stream reach.

- Find an even streambed free of large rocks, weeds, and protruding obstructions that create turbulence. Flow should be uniform and free of eddies, dead water near banks, excessive turbulence, and aquatic vegetation.
- Avoid measuring flow in areas with back eddies. However, this cannot always be avoided. Measure the negative flows in areas with back eddies. Include these negative values in the final flow calculation.

2. Recording Flow Data

Record the following information on a flow measurement form:

- the station location and ID
- the date
- the time the measurement is initiated and ended
- the names of persons measuring flow
- the total stream width and the width of each measurement section
- the midpoint, section depth, and flow velocity for each cross-section

See Tables 3.3 to 3.5 for examples of completed flow-measurement forms. See Table 3.6 for a blank form.

3. Cross-Section Profile

Stretch the measuring tape across the stream at right angles to the direction of flow. When an electronic flow meter is used, the tape does not have to be exactly perpendicular to the bank (direction of flow). If necessary, on smaller, low-flow streams, the cross-section can be modified—by building dikes to cut off dead water and shallow flows and removing rocks, weeds, and debris in the reach of stream 1 to 2 meters upstream from the measurement cross-section. After modifying a streambed, allow the flow to stabilize before starting the measurement.

4. Measuring the Stream Width

Measure and record the stream width between the points where the tape is stretched (water's edge to water's edge). See Figure 3.6.

5. Determining the Number of Flow Cross-Sections

Determine the spacing and location of flow measurement cross-sections. Some judgment is required, depending on the shape of the streambed. Measurements must represent the velocity within the cross-section. Fewer measurements are needed if the stream banks are straight, the depth nearly constant, the bottom free of large obstructions, and the flow homogeneous over a large section. Flow-measurement sections should be of equal width, unless an obstacle or other obstruction prevents an accurate velocity measurement at that point. **No single cross-section should have more than 10 percent of the total flow.** Take the majority of flow measurements in cross-sections of equal width; they will be a constant value in the flow calculation.

Stream width* less than *5 feet. If the stream width is less than 5 feet, cross-section widths are 0.5 ft. See Table 3.5.

Stream width* greater than *5 feet but* less than or equal to *10 feet. If the stream is wider than 5 ft, the minimum number of cross-sections is 10.

Stream width* greater than *10 feet. If the stream is wider than 10 ft, the preferred number of cross-sections is 20 to 30.

Note: Figures 3.6 through 3.15 illustrate an example using a stream that is 10 feet wide.

6. Determining the Midpoint of the Cross-Section

Divide the cross-section width in half to find the midpoint of the cross-section (see Figure 3.7).

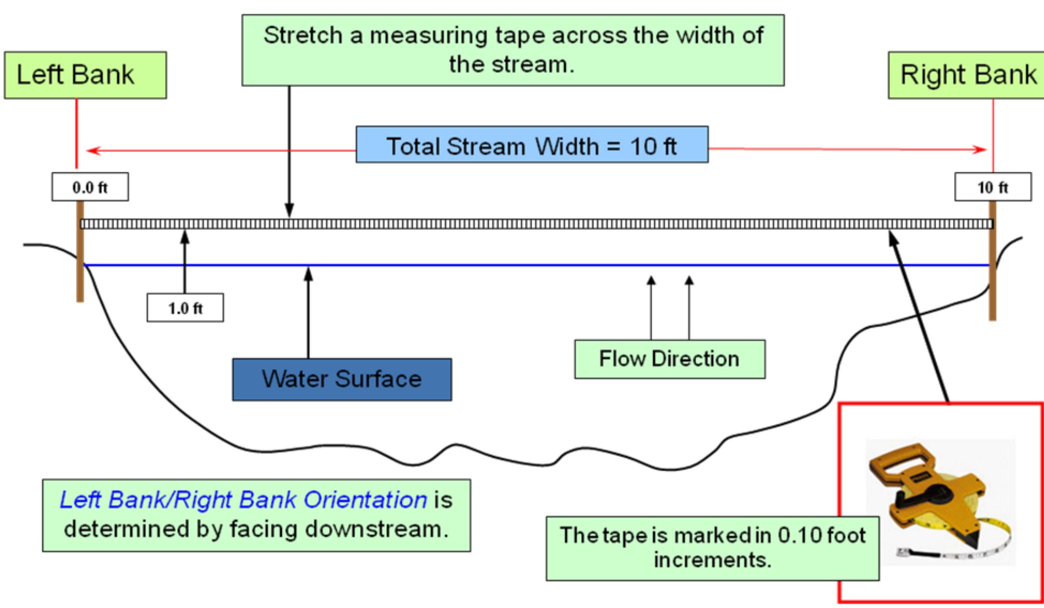


Figure 3.6. Measuring the stream width.

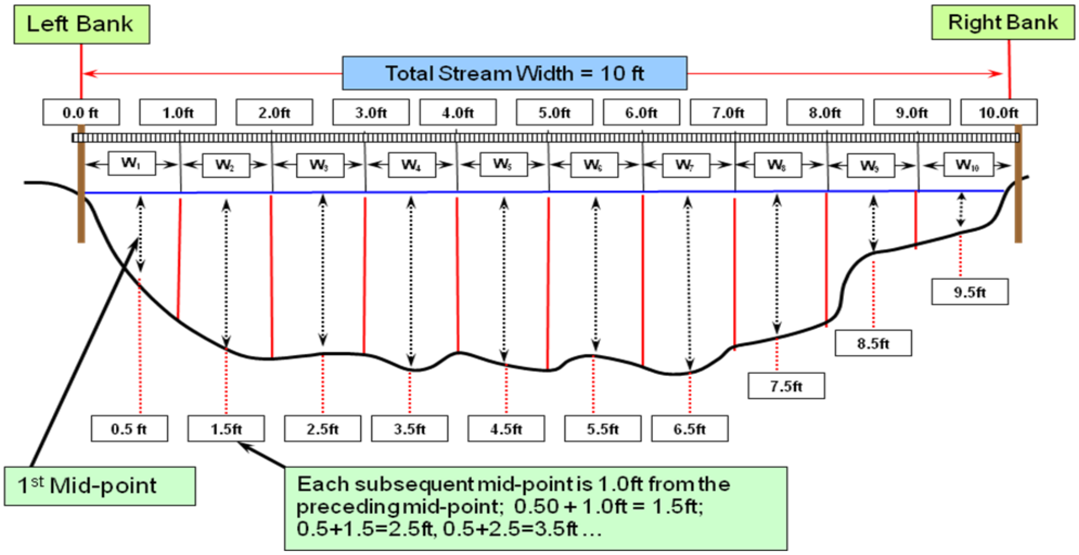


Figure 3.7. Determining the midpoint of the cross-section.

7. Determining the Cross-Section Depth

Using a top-setting wading rod measure the depth at the midpoint of the first cross-section and record to the nearest 0.01 ft. See Figure 3.8.

Measure the total depth at each cross-section with the *depth gauge rod*. Each single mark represents 0.10 ft; each double mark, 0.50 ft; and each triple mark, 1.00 ft (see Figure 3.9).

8. Adjusting the Sensor Depth at a Cross-Section

Adjust the position of the sensor to the correct depth at each midpoint. The top setting wading rod is designed so the user to can easily set the sensor at 20, 60, and 80 percent of the total depth. See Figure 3.10.

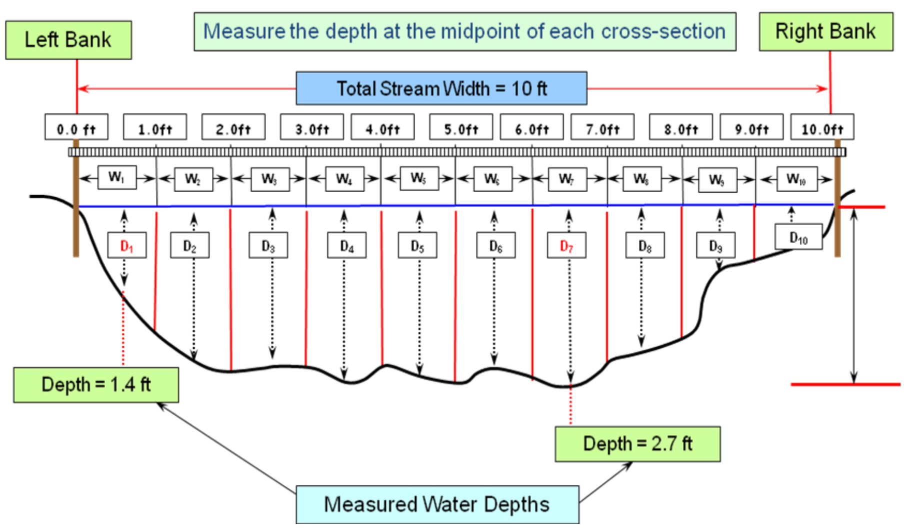


Figure 3.8. Measuring the depth at each midpoint.

For depths ≤2.5 feet. If the depth is 2.5 ft or less, only one velocity measurement is required at each cross-section. To set the sensor at 60 percent of the depth, simply line up the foot scale on the *sliding rod* with the *tenth scale*, located at the top of the depth gauge rod. If, for example, the total depth is 1.4 ft, then line up the *1* on the feet scale with the *4* on the tenths scale. See Figure 3.11.

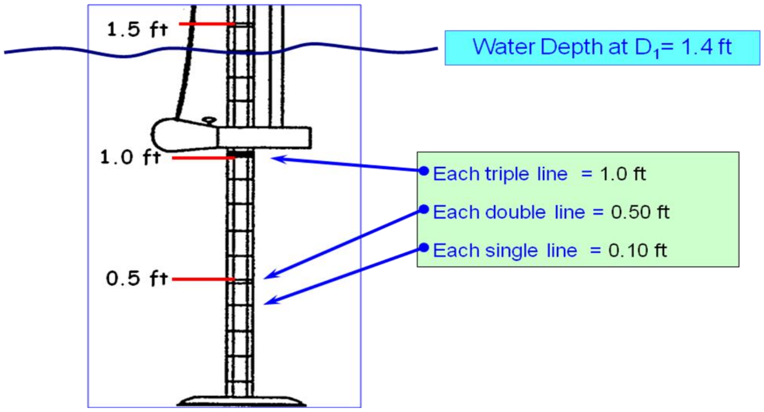


Figure 3.9. Measuring the depth using a top-setting wading rod.

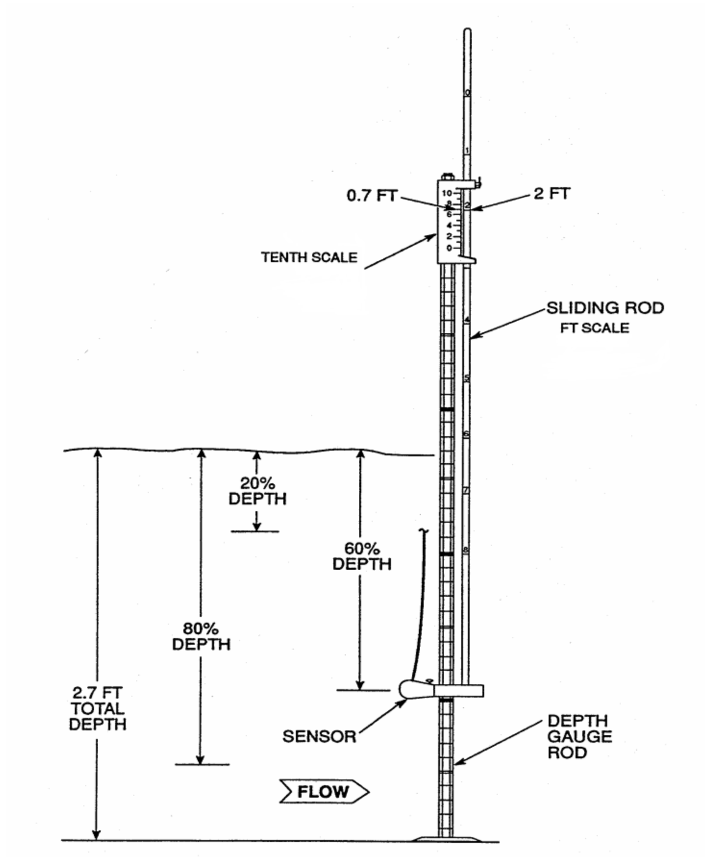


Figure 3.10. Top-setting wading rod.

For depths > 2.5 feet. If the depth is greater than 2.5 ft, take two velocity measurements, at 20 and 80 percent of the total depth. Never set the wading rod at the actual depth. In this case, it would not be set at 2.7 ft.

- ***20 percent of the depth.*** Multiply the total depth by 2. If the total depth is 2.7 ft, the rod would be set at 5.4 ft (2.7 × 2). Line up the *5* on the sliding rod with the *4* on the tenths scale (Figure 3.12). Take a velocity measurement.

- ***80 percent of the depth***. To set the sensor at 80 percent of the depth, divide the total depth by two. For example, the total depth is 2.7 ft and the rod is set at 1.35 ft (2.7 ⁄ 2). Line up the *1* on the sliding rod between the *3* and *4* on the tenths scale (Figure 3.12). Take a velocity measurement. The average of the two velocity measurements is used in the flow calculation.

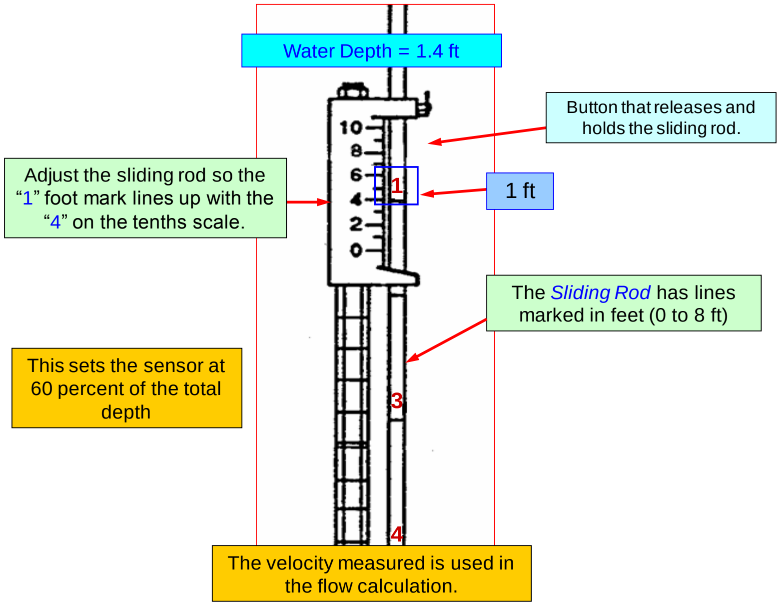


Figure 3.11. Setting the flow sensor at depths ≤ 2.5 feet.

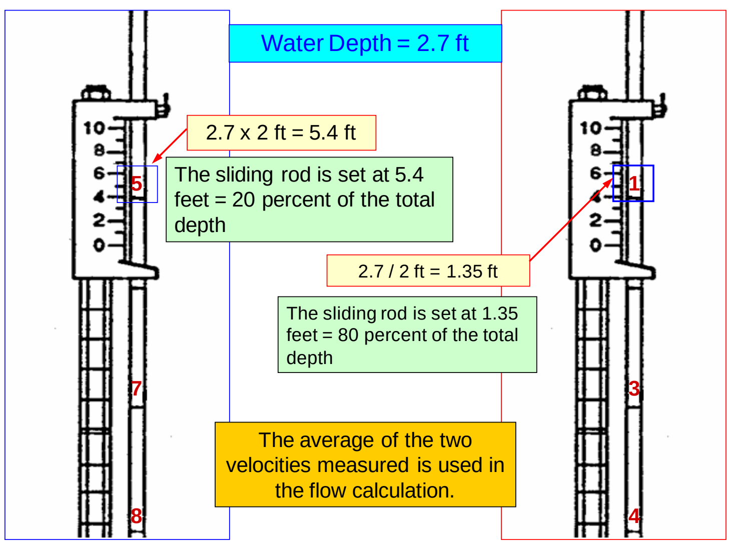


Figure 3.12. Setting the flow sensor at depths > 2.5 feet.

9. Measuring Velocity

To measure velocity:

- Position the flow sensor at the midpoint of the cross-section as described above in "Adjusting the Sensor Depth at a Cross-Section" (see also Figure 3.13). Measure and record the velocity and depth. While measuring velocity with an electronic flow meter, keep the wading rod vertical and the flow sensor perpendicular to the tape, rather than perpendicular to the flow.

- Allow the sensor to adjust to the current for a few seconds. Measure the velocity for a minimum of 20 seconds
- When measuring the flow by wading, stand in the position that least affects the velocity of the water passing the current meter. Stand a minimum of 1.5 ft downstream and off to the side of the flow sensor.

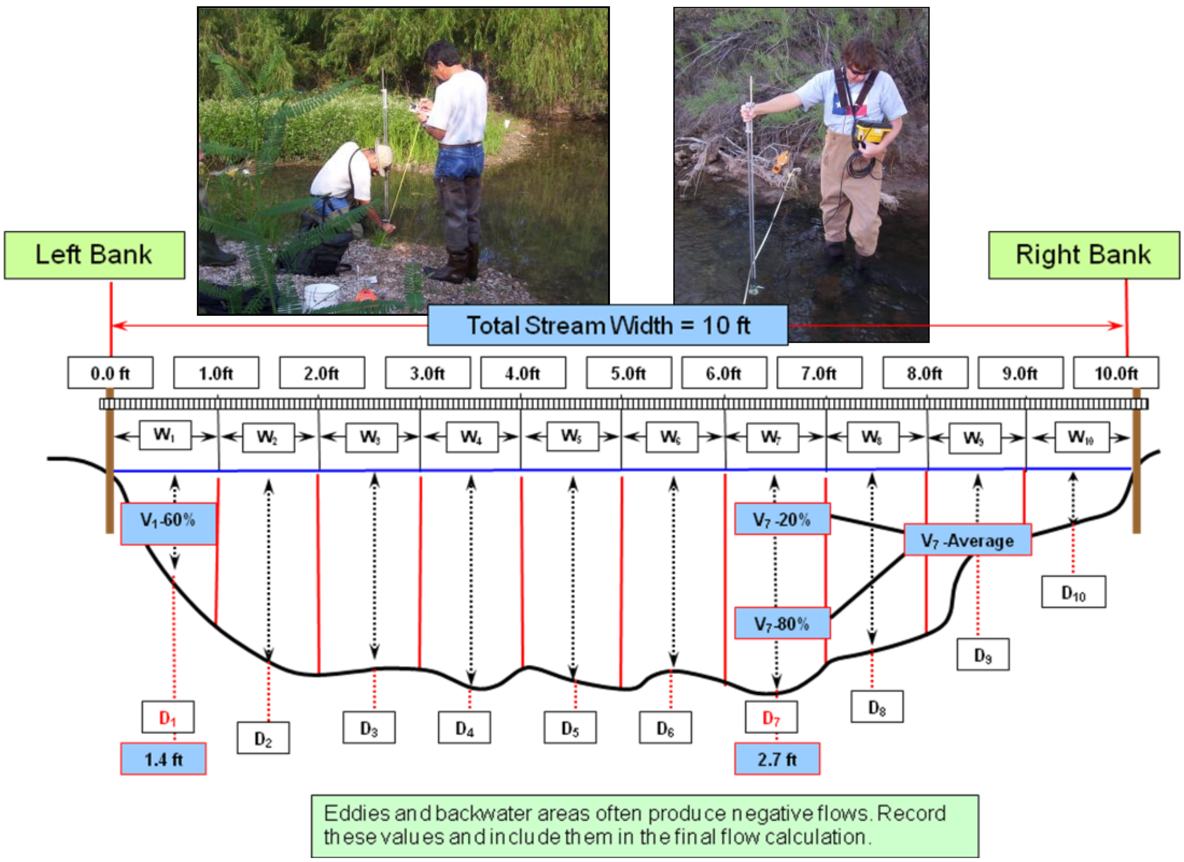


Figure 3.13. Measuring velocity.

10. Recording Flow

Do not round values (other than the final value) when recording flow data. For example, if the velocity is 1.99, do not round to 2.0. Rounding each value on the worksheet will introduce an error in the final value. Record negative velocity values. See Figure 3.14.

Stream Width = 10 ft; Cross Section Width (W) = 1.0 ft						
Cross–Section No. (see Figure 3.12)	Section Midpoint (ft)	Section Depth (D) (ft)	Sensor Depth	Velocity (V)		Discharge (Q) (ft³/s) Q = (W)(D)(V)
				At Point (ft/sec)	Average (ft/sec)	
1	0.5	1.4	1.4		0.85	
2	1.5	2.0	2.0	60%	1.0	
3	2.5	1.9	1.9		1.3	
4	3.5	2.2	2.2		1.7	
5	4.5	2.1	2.1	20%	1.8	
6	5.5	2.5	2.5		1.8	
7	6.5	2.7	5.4	1.8	**1.9**	
			1.35	2.0		
8	7.5	1.7	1.7	80%	1.1	
9	8.5	1.0	1.0		0.75	
10	9.5	0.5	0.5		-0.45	

Figure 3.14. Recording flow data.

11. Calculating Flow

After measuring and recording the velocity and depth at each cross-section, follow these steps to calculate flow:

Calculate flow at each cross-section by multiplying the width (W) × depth (D) × velocity (V) to determine flow in cubic feet per second (cfs or ft^3/sec). See Figure 3.15.

Q = Total Flow (or discharge), W = Width, D = Depth, V = Velocity

$$Q = (W_1 \times D_1 \times V_1) + (W_2 \times D_2 \times V_2) + \ldots (W_n \times Dn \times V_n)$$

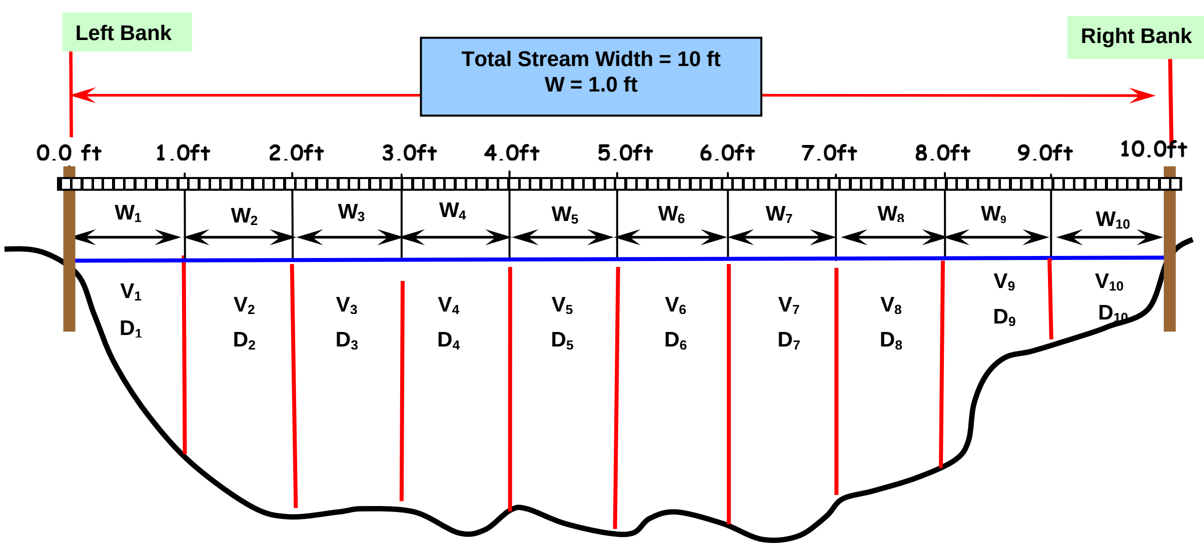


Figure 3.15. Streamflow (discharge) measurement.

- For each individual cross-section flow, **do not** round values. For example, if the calculated flow for a cross-section is 1.23956, do not round. Rounding each value on the worksheet could introduce an error in the final value.
- After calculating the flow for each cross-section, add them together for the total streamflow. See Figure 3.16.

Stream Width = 10 ft; Cross Section Width (W) = 1.0 ft					
Section Midpoint (ft)	Section Depth (D) (ft)	Sensor Depth	Velocity (V)		Discharge (Q) (ft^3/s) Q = (W)(D)(V)
			At Point (ft/sec)	Average (ft/sec)	
0.5	1.4	1.4		0.85	1.19
1.5	2.0	2.0		1.0	2.0
2.5	1.9	1.9		1.3	2.47
3.5	2.2	2.2		1.7	3.74
4.5	2.1	2.1		1.8	3.78
5.5	2.5	2.5		1.8	4.5
6.5	2.7	5.4	1.8	1.9	5.13
		1.35	2.0		
7.5	1.7	1.7		1.1	1.87
8.5	1.0	1.0		0.75	0.75
9.5	0.5	0.5		-0.45	-0.225

Sum the Qs

Q = 25.2 cfs

Figure 3.16. Calculating streamflow (discharge).

12. What to Do with Negative Values

Do not treat cross-sections with negative flow values as zeros. Negative values obtained from areas with back eddies should be subtracted during the summation of the flow for a site.

13. Reporting Final Flow Values

Report instantaneous flow as follows:

- Report values < **10 but** > **0.1 cfs** to the nearest tenth (for example, *9.35* to *9.4*).
- Report values > **10 cfs** to the nearest whole number (for example, *20.62* to *21*).
- Report actual values < **0.1 cfs but ≥ 0.01 cfs**. These values should not be rounded (for example, report *0.07* as “0.07”).
- Report **flow values < 0.01 cfs** as < *0.01*. See Table 3.1.

Examples

See Tables 3.3, 3.4, and 3.5 for examples of completed flow-measurement forms.

Flow-Gauging Stations

Many SWQM stations are sampled at sites where the USGS or the IBWC maintains flow-gauging equipment. A **USGS or IBWC flow-gauging station represents a quarter mile of stream.** A longer distance may apply if it can be shown that no contributions or reductions in flow occur between the gauge and sampling station. USGS gauge stations are statewide; IBWC gauges are located in the Rio Grande Basin. Flow data for these gauging stations can be found on the Web—see Appendix A.

Table 3.3. *Example 1:* Streamflow measurement in a small stream < 5 feet wide and ≤ 2.5 feet deep

Streamflow Measurement

Stream: **OAK CREEK** Date: **5/29/2010**
Station Description: **Oak Creek at US Hwy 90A**
Time Begin: **1545** Time End: **1630** Meter Type: **Marsh-McBirney**
Observers: **BK/MK Total** Stream Width: **5 ft** Section Width (W): **0.5 ft**
Observations:____

Section Midpoint (ft)	Section Depth (ft) (D)	Sensor Depth (ft)	Velocity (V)		Discharge (Q) (ft^3/s) Q = (W)(D)(V)
			At Point (ft/s)	Average (ft/s)	
0.25	0.55			–0.05	–0.01375
0.75	0.80	Nothing is recorded in these columns when the top-setting wading rod is set at 60% of the total depth. The velocity value is recorded in the "Velocity Average" column.		0.11	0.0444
1.25	0.85			0.27	0.11475
1.75	0.90			0.49	0.2205
2.25	1.10			0.58	0.319
2.75	1.50			0.72	0.540
3.25	1.20			0.76	0.456
3.75	0.90			0.76	0.342
4.25	0.75			0.44	0.165
4.75	0.30			–0.25	–0.0375
			Total Flow (Discharge)		**2.16415 ≈ 2.2**

Table 3.4. *Example 2:* Streamflow measurement in a larger stream > 5 feet wide and ≤ 2.5 feet deep.

Streamflow Measurement
Stream: **RED RIVER** Date: **5/28/2010**
Station Description: **Post Oak Creek 40 m Below Sherman WWTP Outfall**
Time Begin: **1542** Time End: **1601** Meter Type: **Marsh-McBirney**
Observers: **CM, EW, DO Total** Stream Width: **26 ft** Section Width (W): **1.3 ft**
Observations:____

Section Midpoint (ft)	Section Depth (ft) (D)	Sensor Depth (ft)	Velocity (V) At Point (ft/s)	Velocity (V) Average (ft/s)	Discharge (Q) (ft^3/s) Q = (W)(D)(V)
0.65	0.55			2.03	1.45145
1.95	0.40			2.04	1.0608
3.25	0.42	Nothing is recorded in these columns when the top-setting wading rod is set at 60% of the total depth. The velocity value is recorded in the "Velocity Average" column.		2.02	1.10292
4.55	0.38			1.77	0.87438
5.25	0.40			1.75	0.910
7.15	0.42			1.93	1.05378
8.45	0.40			1.99	1.0348
9.75	0.37			1.92	0.92352
11.05	0.37			1.56	0.75036
12.35	0.43			1.32	0.73788
13.65	0.40			1.36	0.7072
14.95	0.42			1.33	0.72618
16.25	0.40			1.35	0.702
17.55	0.45			1.64	0.9594
18.85	0.48			1.70	1.0608
20.15	0.48			2.00	1.248
21.45	0.50			1.95	1.2675
22.75	0.40			2.18	1.1336
24.05	0.48			1.71	1.06704
25.35	0.50			0.60	0.390
			Total Flow (Discharge)		**19.16161 ≈ 19.2**

Table 3.5. *Example 3:* Streamflow measurement in a larger stream > 5 feet wide and > 2.5 feet deep.

Streamflow Measurement

Stream: **ARROYO COLORADO** Date: **6/16/2010**
Station Description: **Downstream of Harlingen WWTP**
Time Begin: **1400** Time End: **1445** Meter Type: **Marsh-McBirney**
Observers: **JD, CK Total** Stream Width: **47.5 ft** Section Width (W): **2.375 ft**
Observations: Note that the starting point is at 3.5 ft on the measuring tape and not zero.

Section Midpoint (ft)	Section Depth (ft) (D)	Sensor Depth (ft)		Velocity (V) At Point (ft/sec)	Velocity (V) Average (ft/sec)	Discharge (Q) (ft^3/s) Q = (W)(D)(V)
4.70	0.73				0.65	1.1269375
7.08	1.10				1.08	2.8215
9.45	1.85				0.90	3.954375
11.83	2.20				1.05	5.48625
14.20	2.20				1.44	7.524
16.58	2.45				1.09	6.3424375
18.95	2.55	20	5.1	1.75	1.76	10.659
		80	1.27	1.76		
21.33	2.60	20	5.2	1.79	1.56	9.633
		80	1.3	1.32		
23.70	2.70	20	5.4	1.63	1.45	9.298125
		80	1.35	1.26		
26.10	3.05	20	6.1	1.68	1.42	10.286125
		80	1.525	1.15		
28.48	3.10	20	6.2	1.23	0.96	7.068
		80	1.55	0.69		
30.85	2.90	20	5.8	1.22	1.06	7.30075
		80	1.45	0.89		
33.23	2.84	20	5.67	0.60	0.49	3.30505
		80	1.42	0.37		
35.60	2.65	20	5.3	0.80	0.51	3.2098125
		80	1.325	0.21		
37.98	2.65	20	5.3	0.85	0.91	5.7273125
		80	1.325	0.96		
40.35	2.20				0.28	1.463
42.73	2.30				0.16	0.874
45.10	2.05				0.51	2.4830625
47.48	1.10				0.49	1.280125
49.86	0.65				0.62	0.957125
				Total Flow (Discharge)		**100.8 ≈ 101**

Table 3.6. Streamflow (discharge) measurement form.

Streamflow (Discharge) Measurement Form

Stream:____Date:_______________
Station ____
Description:____
Time Begin:_____________ Time End: _____________Meter Type:_______________
Observers: _______________Total Stream Width: _________Section Width (W):________
Observations:____

Section Midpoint (ft)	Section Depth (ft) (D)	Sensor Depth (ft)	Velocity (V) At Point (ft/s)	Velocity (V) Average (ft/s)	Flow (Q) (ft^3/s) Q = (W)(D)(V)
$m^3/s \times 35.3 = ft^3/s$			**Total Flow (Discharge)**		

TCEQ-20117 (Rev. 04-22-2004)

Guidelines for Using a SonTek FlowTracker (Acoustic Doppler Velocimeter)

This section summarizes the use of the SonTek FlowTracker for flow measurement. While this section provides information on the basic use of this instrument it does not contain the level of detail found in the *FlowTracker Handheld ADV® Operation Manual*. Periodically, check the SonTek Web site for manual and firmware upgrades (see Appendix A). If using a similar instrument (e.g., the OTT Hydrometry Acoustic Digital Current Meter) refer to the manufacturer's operations manual. Follow the flow-measurement method described in that manual.

Under appropriate conditions the FlowTracker can be used in place of electronic and mechanical flow meters; it is also mounted on a top-setting wading rod. The same procedures outlined for use with electronic or mechanical flow meters apply to the FlowTracker. The main difference is that the FlowTracker records all of the data and calculates the flow.

Note: When using the FlowTracker in saltwater, a sacrificial zinc anode should be installed on the probe for corrosion protection.

Follow steps 1 through 9 in the preceding section, "Procedures for Measuring Flow." In brief, the flow-measurement site should be within a relatively straight reach. The streambed should be relatively uniform, with few boulders, and free of debris and heavy aquatic growth. The flow should be relatively uniform and free of eddies, slack water, and excessive turbulence.

The stream width is measured and divided into the appropriate number of cross-sections. For detailed information on the cross-section profile, see the preceding sections "Measuring the Stream Width," "Determining the Number of Flow Cross-Sections," "Determining the Midpoint of the Cross-Section," "Determining the Cross-Section Depth," and "Adjusting the Sensor Depth at a Cross-Section."

Getting Started with the Equipment

Hold the *On/Off* key for "1" second. This will display the firmware version and the current date and time from the internal clock (see Figure 3.17). Press *Enter* to display the *Main Menu*.

```
  FlowTracker 2.3
2001/04/01  08:10:25
  Press Enter Key
   For Main Menu
```

Figure 3.17. Start-up screen.

Important note: Always return to the *Main Menu* before turning the system off to ensure all data are properly saved.

Setup Parameters Menu

For more detailed instructions, see the FlowTracker operations manual, Section 2.4, "Setup Parameters Menu."

From the *Main Menu*, press “1” to access the Setup Parameters Menu, which contains the parameters that determine how the FlowTracker collects data. These parameters are generally set once and do not need to be reset with each use (see Figure 3.18).

```
    Main Menu
1: Setup Parameters
2: System Functions
3: Start Data Run
```

Figure 3.18. Main Menu screen.

Units

The output needs to be in *English* units. To set the units to English, press “1” from the Setup Parameters Menu and then press “1.”

Average Time

The average time (*Avg Time*) specifies the amount of data to be collected at each cross-section (Figure 3.18). Average time is specified in 1-second intervals from 10 to 100 seconds. Measure the velocity for a minimum of 40 seconds at each cross-section. Press “2” from the Setup Parameters Menu and set the *Avg Time* by typing in “40” seconds.

```
1: Units (English)
2: Avg Time (40 s)
3: Mode (Discharge)
ENTER: More Options
```

Figure 3.19. Setup parameters—Average Time and Discharge Mode screen.

Data-Collection Mode

The *Mode* option determines the procedure for collecting at a series of cross-sections. **Flow is measured in the discharge mode.** To set the *Data-Collection Mode*, press “3” from the Setup Parameters Menu and press “1” for *Discharge Mode* (Figure 3.19). Discharge Mode allows a sequence of measurements needed to calculated streamflow (Figure 3.20).

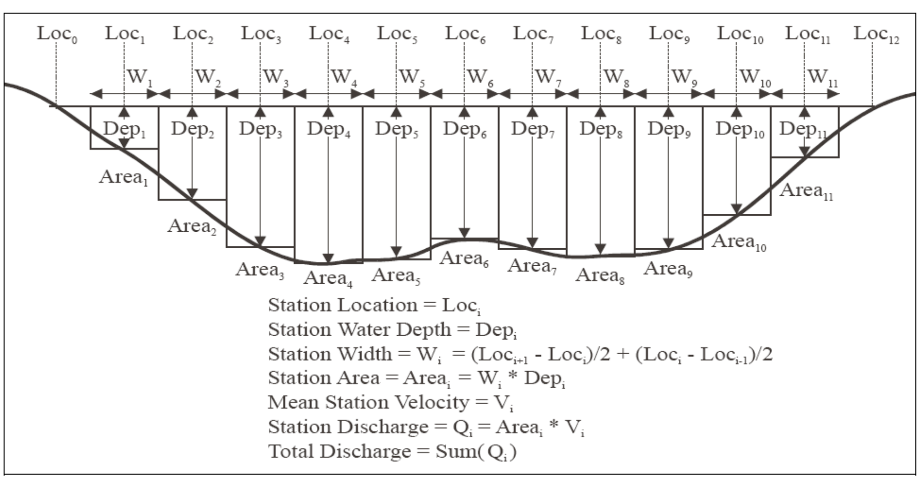


Figure 3.20. Streamflow-measurement method.

Salinity

Since salinity affects the speed of sound, FlowTracker uses a constant to measure velocity. Freshwater has a salinity of “0,” which is the default salinity-parameter setting.

System Functions Menu

The *System Functions* menu provides access to items that should be checked periodically, but are not directly related to data collection. To view the menu, press “2” on the Main Menu screen (see Figure 3.17). For additional information, refer to the FlowTracker operation manual, Section 2.5. Figure 3.21 gives a list of system functions.

```
1:View Data File
2:Recorder Status
3:Format Recorder
0=Exit or Enter=More
```

```
4:Temperature Data
5:Battery Data
6:Raw Velocity Data
0=Exit or Enter=More
```

```
7:Auto QC Test
8:Show Config
9:Set System Clock
0=Exit or Enter=More
```

Figure 3.21. System Function screens.

Starting Data Collection in the Discharge Mode

The following steps describe the data collection sequence in Discharge Mode. For more detailed information, refer to the FlowTracker operation manual, Section 5.3.

1. Venting the Handheld Controller

The FlowTracker is completely sealed, which can cause problems. Changes in temperature or barometric pressure can result in a difference between the device’s internal pressure and atmospheric pressure that can affect the keypad and operating system. To avoid those problems, the handheld controller must be vented before every data-collection run.

To vent the keypad, loosen the small silver cap next to the communication cable. The pressure will equalize in a few seconds. When finished, tighten the cap. When storing or shipping a handheld controller, leave the silver cap loose to let the system acclimate to pressure changes.

Keypad

For detailed information on the keypad functions, refer to the FlowTracker operation manual, Section 2.2. Figure 3.22 depicts the keypad for Firmware version 3.0 or higher.

Figure 3.22. FlowTracker keypad.

2. Entering the Data File Name

From the Main Menu, press “3” to *Start Data Run*. This will display the *Data File Name* menu. Press “1” to enter a file name. This is required. The file, a maximum of 8 characters, can be either letters or numbers. For example, use the Station ID *13208* (see Figure 3.23).

```
   Data File Name
1: Name (none)
2: Extension (none)
9: Accept name
```

Figure 3.23. Data File Name menu.

To enter a number, simply type it. To enter a letter, type the number on the key pad and use the *ABC+* and *ABC–* keys to scroll through the alphabet (see Figure 3.22). After the letter is displayed, type any number to enter the next letter and continue to use the *ABC* keys. Press *Enter* to complete the file name, which will appear in parentheses on the screen. Press “9” to *Accept Name* when ready to start data collection. The next screen will display starting gauge information.

3. Staff and Gauge Height

A menu allowing for entry of staff and gauge height will be displayed after you have entered the data file name. Staff and gauge height values can be entered by pressing “1” and “4,” respectively (see Figure 3.24). These values are used to document the data set but have no effect on operation; they are optional. When ready, press *Next Station* to continue.

```
1: Staff Ht 0.00
4: Gauge Ht 0.00
7: Rated Q 0.00
Next Stn When Ready
```

Figure 3.24. Staff and Gauge Height menu.

4. Set the Starting Edge

Next, set the starting-edge information. When *Next Station* is pressed in the previous step the *Starting Edge* screen will be displayed (Figure 3.25). On the keypad (Figure 3.22), press the *Set Location* key to set the starting edge of the water, *Loc* (see Figure 3.22). This is usually zero and will also be station zero (*Stn 0*). Press the *Set Depth* key to set the starting edge of the water depth, *Dep*, also usually zero. Next, press either the *LEW* or *REW* key.

The *LEW* (left edge of water) and *REW* (right edge of water) keys are used to specify the starting or ending edge of the water. LEW and REW are used to document the data set and have no impact on calculations. Do not press *Measure* at Station 0, the starting edge. When done, press *Next Station* to continue. The starting-edge information is complete.

5. Set Location

The next screen (Figure 3.26) will allow entry of the station information. Press *Set Location* to set the first station location, *Loc 1*. The first location (*Loc 1, Stn 1*) will be the midpoint of the first cross-section and is based on the stream width and the number of flow cross-sections. See above, “Determining the Number of Flow Cross-Sections” and “Determining the Midpoint of the Cross-Section.” For example, if the cross-section width is 1.0 ft and the midpoint of the cross-section is 0.5 ft, set the first location (*Loc 1*, *Stn 1*) at 0.5 ft.

```
    Starting Edge
Loc 0.00    Dep 0.00
LEW         CF 1.00
  Next/Prev Stn Key
```

Figure 3.25. Starting Edge screen.

6. Set Depth

Press *Set Depth* to set the water depth. Input the depth of the water column of *Stn 1* as measured with the top-setting wading rod, then press *Enter*. See above, “Determining the Cross-Section Depth,” for additional information.

```
Stn 1       Mthd .6D
Loc 0.00    Dep 0.00
MDep .6D
           Press Meas
```

Figure 3.26. Set Location screen.

7. Method Selection

After pressing *Set Depth*, you must select a method for determining velocity. The FlowTracker allows you to choose among several methods. These two methods are described above in “Methods for Measuring Flow.”

- The *single-point method* measures velocity at 60 percent of the total depth, *Mthd .6D*. This method used when the water depth at a cross-section is less than 2.5 ft.
- The *two-point method* measures the velocity at 20 and 80 percent of the total depth, *Mthd 2/8.* The method needs to be changed when the depth at a cross-section is greater than 2.5 ft. When this method is used, the system requires two measurements before advancing to the next station.
- Once a method is selected, it will be retained by the system unless changed by the user.

For information on using the top-setting wading rod to set the correct sensor depth, see above, “Adjusting the Sensor Depth.”

On the keypad (Figure 3.22), scroll through the methods using the *Toggle Method+* and *Toggle Method–* keys. The method selected will appear on the *Station Information* screen (Figure 3.25). Keep in mind that the method will need to be switched between *Mthd .6D* to *Mthd 2/8* when the depth is greater or less than 2.5 ft.

8. Measuring Velocity

After correctly setting the station information and setting the probe at the correct depth, press *Measure* to start the collection of water velocity data.

9. Review Quality-Control Indicators

Review QC indicators and decide whether to accept the station velocity measurement, or the repeat measurement after modifying stream conditions or sensor placement. QC indicators are discussed at length in “Quality-Control Indicators,” below.

10. Completing the Station

Press “1” to accept the measurement and move on to the next cross-section, or press “2” to repeat the measurement. See Section 5.3 of the *FlowTracker Operations Manual* for additional information on deleting or repeating a station.

11. Next Station

When a station is complete, the FlowTracker displays the next station. It predicts location, depth, and measurement method for the new station based on the previous input.

At the next station, measure and enter the new depth and station location, then reset the method if necessary. Once the station location increments have been entered twice, the FlowTracker will automatically predict the correct location for the next station. If incorrect, the user should set the location manually. Press *Measure* to start the collection of water velocity data. Repeat this procedure until you have completed all of the cross-sections. Remember to review the QC indicators before moving on to the next station.

Note: At the second location, *Loc 2, Stn 2,* change the width so that the rest of the measurements are done at the correct cross-section width. This change is made after finishing at *Loc 1*, *Stn 1*. At *Loc 2*, *Stn 2*, press *Set Location* and enter the value of the midpoint plus the cross-section width. For example, if the cross-section width is 1.0 ft and the first midpoint is 0.5 ft, enter *1.5 ft*. Remember, when this measurement is accepted the FlowTracker will automatically start using 1.0 ft widths.

12. Set the Ending Edge

Press the *End Section* key when all stations are complete. This activates the *Ending-Edge Screen*. Enter the ending-edge information. On the keypad, press the *Set Location* key to set the ending edge of the water. Press the *Set Depth* key to set the ending edge of the water depth, *Dep*. Next, press either the *LEW* or *REW* key, depending on which key you pressed at the starting edge of the water.

Next, press *Calc Disch* to complete the discharge calculation and close the file. After final discharge calculations are complete, five data screens are available (Figure 3.26). Press *Enter* to move between the five screens. When finished viewing the summary data, press “9” to exit and return to the main menu. Hold the *On/Off* key for “1” second.

13. Calculate Discharge

Next, press *Calc Disch* to complete the discharge calculation and close file. After final discharge calculations are complete, five data screens are available (Figure 3.27). Press *Enter* to move between the five screens. When finished viewing the summary data, press “9” to exit and return to the main menu. Hold the *On/Off* key for “1” second.

Important note: Turning off the FlowTracker from any page other than the *Main Menu* will cause data loss. Always return to the *Main Menu* before powering down.

Quality-Control Indicators

The following indicators should not be considered QC criteria but rather information to assist the user in placement of the sensor and identifying existing stream conditions that may decrease the FlowTracker's ability to measure velocity. When out of range, the user should modify the probe placement or stream conditions to improve values prior to accepting the measurement. If corrective action does not improve the indicator value, the user may look for a more suitable location for flow measurement and start over, or accept the values if no better option is available.

```
File: SITE100.002
Mode: DISCHARGE
2002/06/20  10:02:03
9=Exit or Enter=More
```

```
File: SITE100.002
TotalQ: 15.653 cfs
RatedQ: 16.200 cfs
9=Exit or Enter=More
```

```
Num Stations 27
Mean V 1.43 ft/s
Max V  2.21 ft/s
9=Exit or Enter=More
```

```
Width 23.0 ft
Area 47.3 ft^2
Max Depth 2.50 ft
9=Exit or Enter=More
```

```
Mean SNR 16.5 dB
Mean σV 0.05 ft/s
Boundary BEST
9=Exit or Enter=More
```

Figure 3.27. Final Discharge Measurement screens.

The first QC indicator, associated with the position of the flow sensor relative to the direction of streamflow, is *Flow Angle*. The ideal measurement occurs when the flow is perpendicular to the measuring tape. A flow angle measurement of 0° means the flow is perpendicular; any angle less than 20° will yield reliable results. Try to position the probe perpendicular to the measuring tape. Keep in mind that a flow angle < 20° may not always be possible (Figure 3.28).

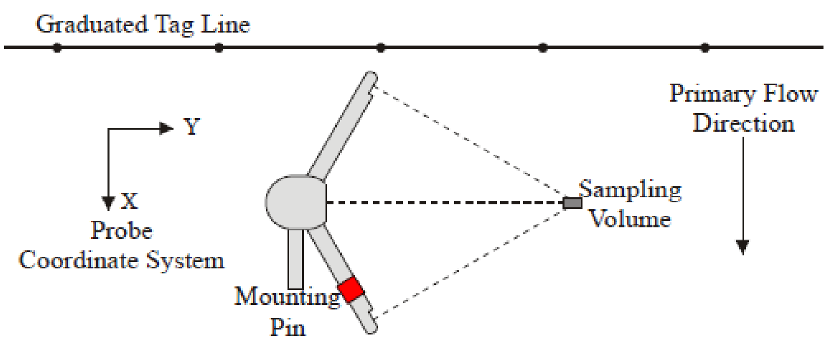


Figure 3.28. FlowTracker probe orientation relative to streamflow.

While a measurement is being made, an updating display shows the velocity and *signal-to-noise ratio* (*SNR*) (Figure 3.29). For best operating conditions the SNR should be greater than 10 decibels. The FlowTracker will display a warning at the end of the measurement if the SNR is less than 4 dB. A low SNR indicates a lack of suspended material in the water. A low SNR can be improved by stirring the sediment upstream of the flow-measurement point.

```
Loc 2.00  MDep .6D
Vel (ft/s) 0.00
SNR (dB)   0.0
Time (sec) 19
```

Figure 3.29. Updating-display screen.

When the velocity measurement is complete, a summary of velocity and quality control data is displayed (see Figure 3.30). In addition to SNR and Flow Angle a *standard error of velocity* (σV) is calculated as an accuracy measure of the velocity data, based on the variability of individual velocities measured during the averaging time.

```
Vel 2.25    σV 0.04
Ang 5°      SNR 15.1
Spikes 0    Bnd BEST
1: Accept   2: Repeat
```

Figure 3.30. Velocity and QC Data screen.

Boundary adjustment or *Boundary QC* is an indicator of interference from underwater objects. The FlowTracker works best away from underwater obstructions. Select a site free of large objects. The FlowTracker records changes required to avoid acoustic interference as *Boundary QC* or *Bnd* (see Figure 3.30). *Boundary QC* describes the effect (if any) of boundary adjustments on the system's performance—automatically determined by the FlowTracker and quantitatively reported as *(0) Best, (1) Good, (2) Fair, or (3) Poor*. The most common are *Best* and *Good*. If Boundary QC is *Fair* or *Poor,* attempt to move away from any instream obstruction.

Spikes are unusually high velocity measurements compared to the average, usually the result of large particles or bubbles. A spike measurement is determined automatically and filtered from the data set by the FlowTracker. The number of spikes, typically *0* or *1,* is displayed on the Velocity and QC Data Screen (see Figure 3.30).

For more details, refer to Section 1.4 of the FlowTracker operations manual.

FlowTracker Software

Software is used to start programs for all major FlowTracker functions. The most commonly used applications are *SonUtils* for downloading data and *FlowTracker* for viewing binary data. Instructions on downloading data using FlowTracker software are provided below. The user may refer to the FlowTracker operations manual for guidance regarding SonUtils. For more details, see Sections 6.0 to 6.4 of the manual. Links to the FlowTracker user manuals are available in the software.

Downloading Data Files

To download data files:

- Connect the power-communication cable from the FlowTracker to COM1 of the PC.
- It is not necessary to turn the FlowTracker on manually (using the keypad) to download data via the PC; however, batteries must be installed.

- Start the FlowTracker software by clicking on the desktop icon or via *Start | Programs | SonTek Software | FlowTracker*.
- From the FlowTracker Main Screen (Figure 3.31), click the *Connect to a FlowTracker* icon to establish communication with the FlowTracker and retrieve the recorder directory. Establishing the connection may take a few minutes. Once the device is connected, the keypad will display "FlowTracker Under External Control."
- Use the *Recorder* button to locate the file to be downloaded from the FlowTracker, and browse to the location on the PC (*Download File Directory Location*) where you want to save the file (*.WAD). The *Recorder* becomes available once the PC is successfully connected to a FlowTracker.
- Select one or more files from the download recorder directory (see Figure 3. 31).
- Click *Download* to retrieve the files from the FlowTracker and download them to the PC. The downloaded files will have the file extension **.WAD.*

For detailed instructions, see Section 6.4 of the FlowTracker operation manual.

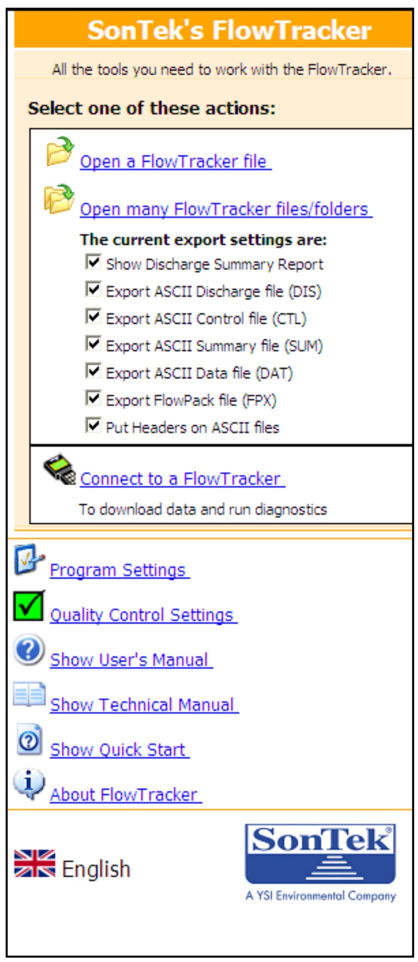


Figure 3.31. FlowTracker main screen.

View Data Reports

FlowTracker files are recorded in a compact binary format. To assess these reports FlowTracker software is used to view the information in the *.WAD file. After downloading data from the FlowTracker open the *.WAD file using the following steps:

- Start the FlowTracker software by clicking on the desktop icon or via *Start | Programs | SonTek Software | FlowTracker*.
- From the FlowTracker main menu, click the *Program Settings* button to specify output in *English Units* and the file download directory—typically the *Same Directory as Data File* (see Figure 3.32). Specifying the directory is optional, and only used if you intend to download to the same directory every time.
- Click the *Open a FlowTracker File* button to navigate to the *.WAD file. Click *Open* once the file is selected.
- Once selected and opened, the *.WAD file will load in a few moments.

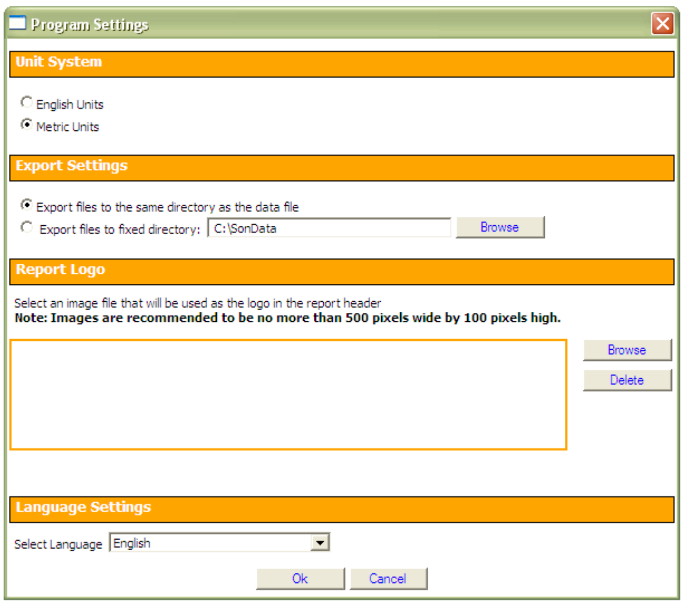


Figure 3.32. FlowExporter options window.

- FlowTracker processes information in the *.WAD file and generates various output reports;
  - Discharge Measurement Summary (see Figure 3.33)
  - Quality Control Summary (see Figures 3.34)
- All output reports can be loaded onto the screen. It is possible to copy and paste the report information into Notepad or Excel. You may also print or save the reports as a PDF for your records.
- Press *Disconnect* when finished.
- For more detailed instructions, refer to Section 6.5 of the FlowTracker operation manual.

Data Retention

The downloaded files are saved for QA purposes under the same retention schedule specified for other field data records. Make a note of the file names in the field record for that sampling.

Discharge Measurement Summary

Date Generated: Fri Aug 25 2006

File Information	
File Name	DemoData.wad
Start Date and Time	2001/08/15 12:58:16

Site Details
Site Name
Operator(s)

System Information	
Sensor Type	FlowTracker
Serial #	P63
CPU Firmware Version	2.0
	1.95

Units	(Metric Units)
Distance	m
Velocity	m/s
Area	m^2
Discharge	m^3/s

Summary			
Averaging Int.	40	# Stations	25
Start Edge	LEW	Total Width	73.762
Mean SNR	24.3 dB	Total Area	31.111
Mean Temp	27.12 °C	Mean Depth	0.422
Disch. Equation	Mid-Section	Mean Velocity	0.2783
		Total Discharge	**8.6585**

Discharge Uncertainty

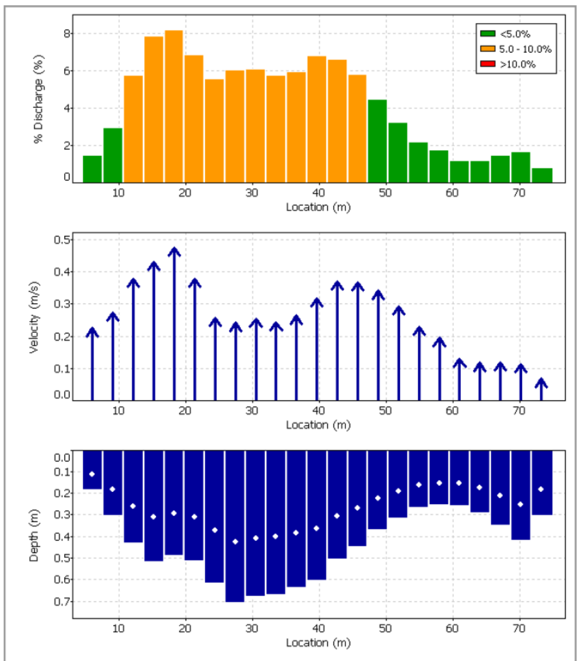
Category	ISO	Stats
Accuracy	1.0%	1.0%
Depth	0.1%	1.2%
Velocity	0.5%	1.6%
Width	0.1%	0.1%
Method	1.8%	-
# Stations	2.0%	-
Overall	**2.9%**	**2.3%**

Measurement Results

St	Clock	Loc	Method	Depth	%Dep	MeasD	Vel	CorrFact	MeanV	Area	Flow	%Q
0	12:58	3.05	None	0.000	0.0	0.000	0.0000	1.00	0.0000	0.000	0.0000	0.0
1	12:58	6.10	0.6	0.186	0.6	0.074	0.2264	1.00	0.2264	0.567	0.1283	1.5
2	12:59	9.14	0.6	0.305	0.6	0.122	0.2748	1.00	0.2748	0.929	0.2553	2.9
3	13:02	12.19	0.6	0.433	0.6	0.173	0.3781	1.00	0.3781	1.319	0.4988	5.8
4	13:03	15.24	0.6	0.518	0.6	0.207	0.4307	1.00	0.4307	1.579	0.6801	7.9
5	13:04	18.29	0.6	0.491	0.6	0.196	0.4748	1.00	0.4748	1.496	0.7101	8.2
6	13:05	21.34	0.6	0.515	0.6	0.206	0.3789	1.00	0.3789	1.570	0.5949	6.9
7	13:06	24.38	0.6	0.619	0.6	0.247	0.2571	1.00	0.2571	1.886	0.4848	5.6
8	13:08	27.43	0.6	0.710	0.6	0.284	0.2429	1.00	0.2429	2.164	0.5257	6.1
9	13:09	30.48	0.6	0.680	0.6	0.272	0.2553	1.00	0.2553	2.072	0.5289	6.1
10	13:10	33.53	0.6	0.671	0.6	0.268	0.2436	1.00	0.2436	2.044	0.4978	5.7
11	13:11	36.58	0.6	0.640	0.6	0.256	0.2644	1.00	0.2644	1.951	0.5158	6.0
12	13:12	39.62	0.6	0.607	0.6	0.243	0.3181	1.00	0.3181	1.849	0.5880	6.8
13	13:13	42.67	0.6	0.509	0.6	0.204	0.3704	1.00	0.3704	1.551	0.5747	6.6
14	13:14	45.72	0.6	0.451	0.6	0.180	0.3675	1.00	0.3675	1.375	0.5053	5.8
15	13:15	48.77	0.6	0.372	0.6	0.149	0.3421	1.00	0.3421	1.133	0.3877	4.5
16	13:16	51.82	0.6	0.317	0.6	0.127	0.2935	1.00	0.2935	0.966	0.2835	3.3
17	13:18	54.86	0.6	0.271	0.6	0.108	0.2303	1.00	0.2303	0.827	0.1904	2.2
18	13:19	57.91	0.6	0.256	0.6	0.102	0.1952	1.00	0.1952	0.780	0.1523	1.8
19	13:20	60.96	0.6	0.259	0.6	0.104	0.1314	1.00	0.1314	0.789	0.1037	1.2
20	13:21	64.01	0.6	0.293	0.6	0.117	0.1193	1.00	0.1193	0.892	0.1064	1.2
21	13:22	67.06	0.6	0.351	0.6	0.140	0.1196	1.00	0.1196	1.068	0.1278	1.5
22	13:23	70.10	0.6	0.421	0.6	0.168	0.1147	1.00	0.1147	1.282	0.1470	1.7
23	*13:25*	*73.15*	*0.6*	*0.305*	*0.6*	*0.122*	*0.0696*	*1.00*	*0.0696*	*1.022*	*0.0711*	*0.8*
24	13:25	76.81	None	0.000	0.0	0.000	0.0000	1.00	0.0000	0.000	0.0000	0.0

Rows in italics indicate a QC warning. See the Quality Control page of this report for more information.

Figure 3.33. Discharge Measurement Summary report.



Quality Control

St	Loc	%Dep	Message
23	73.15	0.6	High angle: 27

Figure 3.34. Quality Control Summary report.

Portable Cutthroat Flume

A portable stainless steel cutthroat flume can be used to measure flow in very narrow and shallow streams where flow meters are not effective (see Figure 3.35). In general, this method channels all of the flow through the flume and a measurement is made from a staff gauge. The staff gauge value is converted to a flow value (ft^3/s) using a cutthroat-flume table (see Table 3.7). A cutthroat flume is used in situations where the expected flow is less than 2 ft^3/s and the maximum flow through the flume is 0.74 ft. The throat of the flume can be adjusted to widths of 1, 2, 4, or 8 in depending on the expected flow. For routine monitoring, the 2 in and 4 in widths are generally the most appropriate (see Figure 3.35).

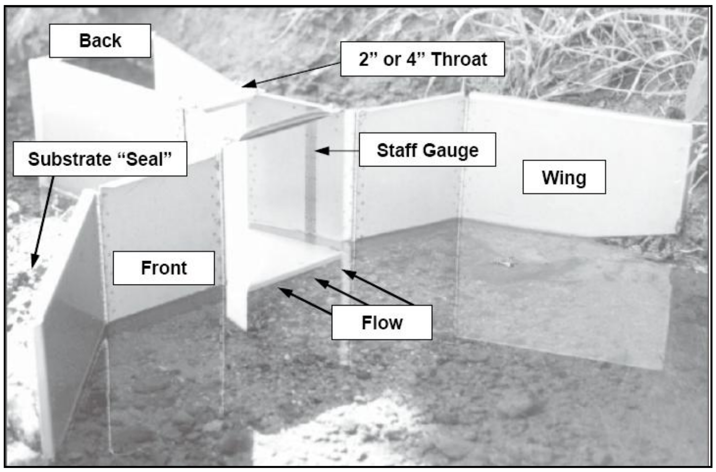


Figure 3.35. Portable cutthroat flume (Baski, Inc.).

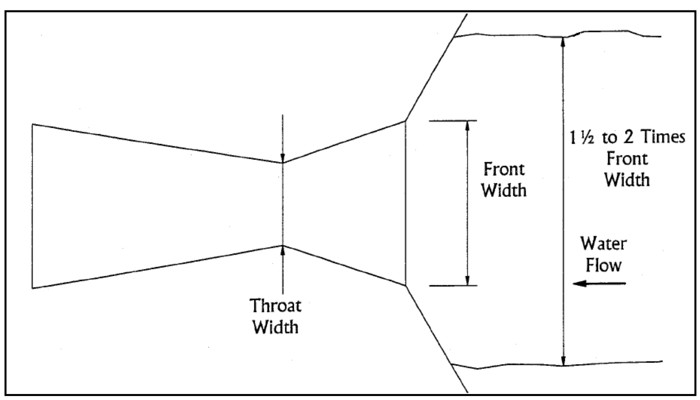


Figure 3.36. Top view of the cutthroat flume (Baski, Inc.).

Cutthroat-Flume Method

- Find an area where all of the streamflow can be diverted through the flume neck.
- Set the flume firmly on the stream bottom. Make sure the flume is level from side to side and front to back.
- Use a bubble level to determine if the instrument is level on the stream bottom.
- Extend the 19-inch wing walls out as far as possible blocking any flow (see Figure 3.36).

- Create a dam behind the wing walls with substrate material, preferably clay. This helps to keep all of the flow diverted through the flume, increasing the accuracy of the measurement.
- Read the measurement off the staff gauge—mounted on the inside of the flume wall, marked in hundredths of a foot, it measures the amount of water passing through the flume.
- Record the measurement off the staff gauge and convert it to cfs using Table 3.7.

Table 3.7. Cutthroat-flume flow conversion.

Gauge Height (ft)	2 in	4 in	Gauge Height (ft)	2 in	4 in
0.01	0.000102	0.000208	0.38	0.147	0.300
0.02	0.000408	0.000832	0.39	0.155	0.316
0.03	0.000918	0.00187	0.40	0.163	0.333
0.04	0.00163	0.00333	0.41	0.171	0.350
0.05	0.00250	0.0052	0.42	0.180	0.367
0.06	0.00367	0.00749	0.43	0.189	0.385
0.07	0.005	0.0102	0.44	0.197	0.403
0.08	0.00653	0.0133	0.45	0.207	0.421
0.09	0.00826	0.0168	0.46	0.216	0.440
0.10	0.0102	0.0208	0.47	0.225	0.459
0.11	0.0123	0.0252	0.48	0.235	0.479
0.12	0.0147	0.030	0.49	0.245	0.499
0.13	0.0172	0.0352	0.50	0.255	0.520
0.14	0.0200	0.0408	0.51	0.265	0.541
0.15	0.0229	0.0468	0.52	0.276	0.562
0.16	0.0261	0.0532	0.53	0.287	0.584
0.17	0.0295	0.0601	0.54	0.297	0.607
0.18	0.033	0.0674	0.55	0.309	0.629
0.19	0.0368	0.0751	0.56	0.320	0.652
0.20	0.0408	0.0832	0.57	0.331	0.676
0.21	0.045	0.0917	0.58	0.343	0.700
0.22	0.0494	0.101	0.59	0.355	0.724
0.23	0.054	0.110	0.60	0.367	0.749
0.24	0.0588	0.120	0.61	0.380	0.774
0.25	0.0638	0.130	0.62	0.392	0.800
0.26	0.069	0.141	0.63	0.405	0.826
0.27	0.0744	0.152	0.64	0.418	0.852
0.28	0.080	0.163	0.65	0.431	0.879
0.29	0.0858	0.175	0.66	0.444	0.906
0.30	0.0918	0.187	0.67	0.458	0.934
0.31	0.098	0.200	0.68	0.472	0.962
0.32	0.104	0.213	0.69	0.486	0.990
0.33	0.111	0.227	0.70	0.500	1.02
0.34	0.118	0.240	0.71	0.514	1.05
0.35	0.125	0.255	0.72	0.529	1.08
0.36	0.132	0.270	0.73	0.544	1.11
0.37	0.140	0.285	0.74	0.559	1.14

Flow Estimate (ft^3/s)

Parameter Code 74069

Flow-estimate data may be used for a non–tidally influenced stream. Flow estimates are generally subjective measurements based on the ability of experienced field staffers to estimate distances, depths, and velocities. Never use estimated flow in place of measured flow for baseline SWQM stations, in biological assessments, or for other regulatory sampling. The TCEQ evaluates alternative methods for estimating flow case by case.

How to Estimate Flow

- Choose a reach of the stream where it is possible to estimate its cross-section and velocity.
- Estimate the stream width (ft) at that reach and record the estimate.
- Estimate the average stream depth (ft) at that reach and record the estimate.
- Estimate stream velocity (ft/s) at that reach and record. A good method is to time the travel of a piece of floating debris. To use this method from a bridge, measure its width. Have one person drop a floating object (that can be distinguished from other floating material) at the upstream side of the bridge and say, “Start.” The person on the downstream side of the bridge stops the clock when the floating object reaches the downstream side. Divide the bridge width by the number of seconds to calculate the velocity. The velocity can be measured at multiple locations along the bridge, and those velocities averaged. If you are doing this alone, watch out for road traffic.
- Multiply stream width (ft) by average stream depth (ft) to determine the cross-sectional area (ft^2), which, when multiplied by the stream velocity (ft/s) and a correction constant, gives an estimated flow (ft^3/s).

  Example*:* The stream width was around 15 ft. It appeared the average depth on this reach was about 0.75 ft. The sampler timed a piece of floating debris as it moved a distance of 10 ft in 25 seconds (= 2.5 ft/sec) downstream over the reach. An estimated flow with a smooth bottom was calculated, using the following formula:

  width × depth × velocity × A (correction factor) = estimated flow

  15 ft (width) × 0.75 ft (depth) × 2.5 ft/s (velocity) × 0.9 =25 ft^3/s (cfs)

  A is a correction constant: 0.8 for rough bottom and 0.9 for smooth bottom

Experienced field personnel are able to estimate flow to within 20 percent of actual flow values less than 50 ft^3/s. The best way to develop this skill is to practice estimating flow before making measurements at all monitoring visits to nontidally influenced flowing streams. Then compare estimated flows with those obtained from USGS gauges or from instantaneous flow measurements.

Estimating Flow from a Staff Gauge

At routine sampling sites on wadeable streams, it is often useful to establish a staff gauge. This will enable the creation of a flowchart (rating curve) after a number of visits. Flow charts are useful because they can display a lot of information in a concise format. They are inexpensive to establish and only require four or five visits at different flow severities in order to establish a representative graph.

Purchase a standard staff gauge from a vendor (for example, Ben Meadows or Forestry

Supply) or a more inexpensive T-post from any hardware or farm supply store. Place the gauge on a permanent structure, such as a tree or piling in the water or on the bank (see Figure 3.37). The staff gauge must be placed in an area with laminar flow. Avoid backwater areas, eddy pools, and areas with uneven flow (riffles).

It is best to establish the gauge during low-water conditions so the zero point can be located on the bottom of the streambed, or at the lowest expected flow. If flow falls below the zero point, it is possible to estimate the distance to the water surface below the zero point with a ruler, and graph negative numbers. Once the staff gauge is installed, take a minimum of four instantaneous flow measurements according to SWQM procedures. The water depth on the established staff gauge (gauge height) must be recorded each time an instantaneous flow measurement is made. By plotting four to 10 instantaneous flow values (along the *y*-axis) versus gauge height (*x*-axis), a flow chart or *rating curve* can be developed. The rating curve allows instantaneous flow to be determined by simply reading the gauge height and identifying the associated instantaneous-flow value from the curve (Figures 3.38, 3.39).

Figure 3.37. Staff gauge.

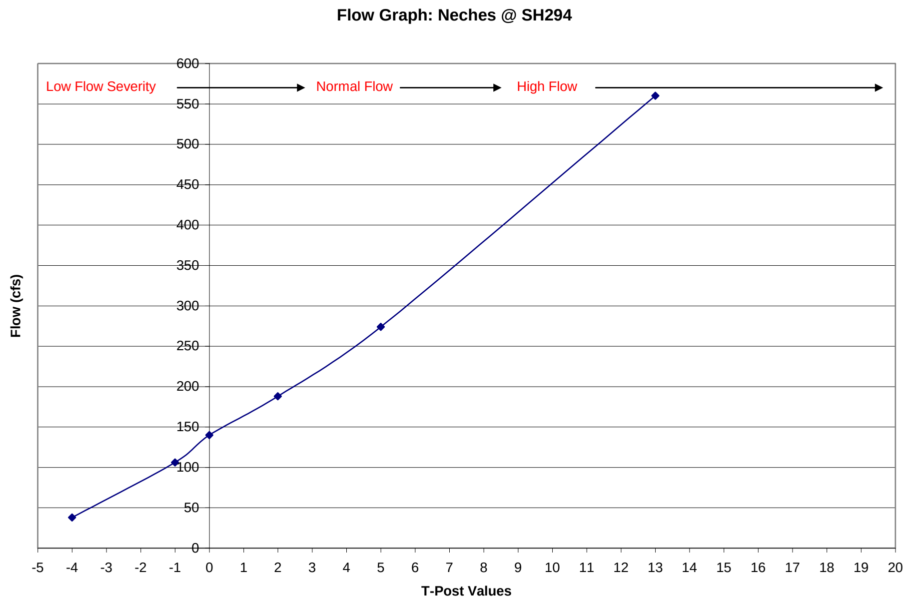
Enter data into Excel where it can be graphed after several different flow measurements have been taken. Figure 3.38 is an example of a site where the gauge was established during low flow and then a subsequent measurement was made when the stream became intermittent with perennial pool-flow severity.

The two graphs in Figures 3.38 and 3.39 were created in Excel using the “scatter plot with smoothed line” option. In order to have the line drawn between the individual points, it is necessary to hide all the staff-gauge readings (for example, in Figure 3.38, *0.3* to *0.8*) that do not have instantaneous flow values associated with them. These values can be reinserted by clicking on the *x*-axis, then right-clicking the mouse and choosing “format axis,” then “scale.”

Once a flow graph has become established at a site, it is possible to get an accurate flow estimate on a given day without actually measuring flow. The estimate is made by getting a staff gauge reading and interpolating flow from the graph. The most accurate flow estimates are those that fall between the lowest and highest measured flow values. It is possible to extrapolate the graph beyond the last measurement, but note that, once flow goes beyond bank-full stage, the graph changes character and the estimates are less accurate. Flow graphs work best at sites with similar left and right bank angles. They do not work well at locations with low bank angles (for example, less than 20°).

Note: Every rating curve is unique. Some remain very stable over time while others change. For example, high flow events may alter upstream channel characteristics. After several readings fail to fall on the curve, it may be time to revise the rating curve by dropping some older readings.

Flow values determined based on rating curves derived from four to 10 instantaneous flow measurements are reported as flow estimates (parameter code 74069). By establishing a staff-gauge using a larger number of instantaneous flow measurements (for example, 10 to 20) and calculating a statistically significant regression, it is possible to report a flow value based on gauge height as a measured value (parameter code 00061).



Staff Gauge Readings

Figure 3.38. Staff gauge established at low flow.

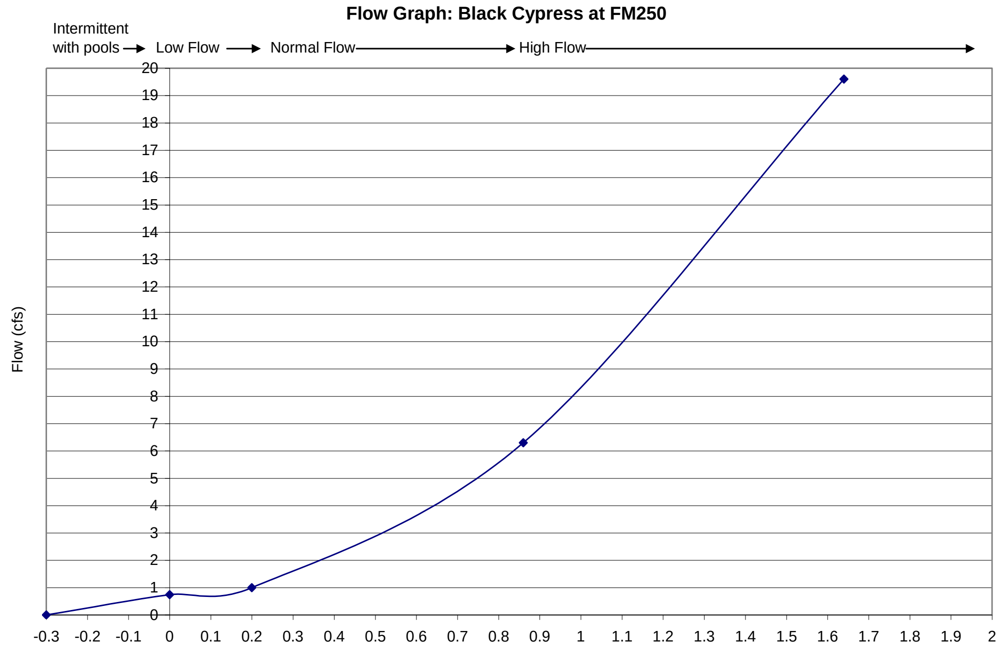


Figure 3.39. Flow graph.